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ABSTRACT

Based on a 15-week student project, this paper surveys the impact of current and expected future robotics technology on the workplace and workers. The monograph is organized into seven chapters. The first chapter introduces the issues of robotics and of social displacement as a result of anticipated growth in the use of industrial robots. In the second chapter, results of a study conducted by the students are reported. The study asked executives of major industries how they were using robots currently and how they planned to increase their use in the future. Technological changes in coal mining and newspaper printing are profiled in the third chapter. In chapter 4, technological changes caused by the introduction of robotics into industry in general are discussed. The fifth chapter examines the capabilities of robots for performing various types of manufacturing jobs; tasks are analyzed in industries such as metalworking, and estimates are made of the number and types of jobs that robots could do. The last two chapters of the monograph discuss short-term transitional issues and human resource policies in the change to a robotic society. Issues such as the role of unions and retraining for displaced workers are included in the discussion. Appendixes to the document include survey documents, the effects of age distribution on unions, and supplementary human resource material. (KC)

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THE IMPACTS OF ROBOTICS ON THE WORKFORCE AND WORKPLACE

June 14, 1981

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This report on the Impacts of robotics on the workforce and workplace is the result of a 15 week student project. Project courses of this type are offered jointly each semester by the School of Urban and Public Affairs, the Department of Social Science and the Depatment of Engineering and Public Policy. This project was also assisted by the Carnegie Mellon Robotics Institute. Projects are student managed with faculty playing primarily an advisory role. Funding for these projects is provided entirely from internal academic sources.

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TABLE OF CONTENTS

1. Introduction 1

1.1 ANTICIPATING THE GROWTH OF INDUSTRIAL ROBOTS 1
1.2 A DESCRIPTION OF INDUSTRIAL ROBOTS 2
1.3 ROBOTS AND ECONOMIC GROWTH 6
1.4 SOCIAL COST 7
1.5 TRAINING AND RETRAINING ISSUES 8
1.5.1 The Roles of Government and Industry 8

2. EXECUTIVE SUMMARY 11

2.1 TECHNOLOGICAL CHANGE IN UNDERGROUND COAL MINING AND NEWSPAPER PRINTING 11
2.2 THE INTRODUCTION OF ROBOTICS INTO INDUSTRY 12
2.2.1 Methodology 12
2.2.2 Reasons For Using Robots 12
2.2.3 Quantifiability of Robot Benefits 12
2.2.4 Organizational Adaptations 13
2.2.5 Trends In The Use Of Robots 13
2.2.6 Retrofitting vs New Plant Installations 14
2.3 CHARACTERIZATION OF ROBOT CAPABILITIES AND MANUFACTURING JOBS 15
2.3.1 Impacts on Great Lakes States 15
2.3.2 The Metalworking Sector 15
2.3.3 Prime Candidates for Robotization 16
2.3.4 Estimates of the Number of Operative Task Robots Could Do 16
2.3.5 Conclusions 17
2.4 SHORT TERM TRANSITIONAL ISSUES 17
2.4.1 Introduction 17
2.4.2 Possible Outcomes for the Labor Force 18
2.4.3 The Role of Unions 18
2.4.4 Relevant Contract Clauses 19
2.4.5 Conclusions 20
2.5 HUMAN RESOURCE POLICIES 22

3. TECHNOLOGICAL CHANGE IN COAL MINING AND NEWSPAPER PRINTING 25

3.1 INTRODUCTION 25
3.2 BITUMINOUS COAL 26
3.2.1 Overview of the Technology 26
3.2.2 The Diffusion of the Continuous Miner 28
3.2.3 Requirements for New Skills 29
3.2.4 Retraining 29
3.2.5 UMWA Policies Toward Automation 31
3.2.6 Summary of the Impacts of the Continuous Miner 34
3.3 NEWSPAPER TYPESETTING 35
3.3.1 Overview of the Technology 35
3.3.2 The Diffusion Of Computerized Typesetting 35
3.4 THE CASE OF THE NEW YORK TIMES AND THE PITTSBURGH PRESS 36
3.4.1 Requirements for New Skills 36
3.4.2 Retraining 37
3.4.3 ITU Policies Toward Automation 38
3.4.4 Summary of the Impacts of Computerized Typesetting 43
3.5 CONCLUSIONS FROM THE CASE STUDIES 43

4. THE INTRODUCTION OF ROBOTICS INTO INDUSTRY 47

4.1 INTRODUCTION 47
4.2 METHODOLOGY 47
4.3 REASONS FOR USING ROBOTS 48
4.3.1 Labor Cost 49
4.3.2 Elimination of Tedious and Dangerous Jobs 51
4.3.3 Output Rate 51
4.3.4 Product Quality 52
4.3.5 Production Flexibility 52
4.3.6 Other Factors 53
4.4 THE DECISION TO IMPLEMENT ROBOTS 54
4.4.1 The Proposal 54
4.4.2 Evaluation of Robot Expenditures 54
4.4.3 Quantifiability of Robot Benefits 57
4.5 ORGANIZATIONAL ADAPTATIONS 58
4.5.1 Informing the Workers 58
4.5.2 Training the Workers 58
4.5.3 Worker Safety 59
4.5.4 Organizational Structure and Managerial Duties 60
4.6 TRENDS IN THE USE OF ROBOTS 60
4.6.1 Industries Using Robots 60
4.6.2 The Diffusion Of Industrial Robots 62
4.6.3 Retrofitting vs New Plant Installations 66

5. CHARACTERIZATION OF ROBOT CAPABILITIES AND MANUFACTURING JOBS 67

5.1 INTRODUCTION 67
5.2 OVERVIEW OF INDUSTRIAL ROBOTS 67
5.2.1 Definition of a Robot 67
5.2.2 Capabilities of a Robot 67
5.3 TASKS ROBOTS CAN PERFORM 68
5.4 THE MANUFACTURING SECTOR 72
5.4.1 The Work Force 72
5.5 DISTRIBUTION OF MANUFACTURING JOBS BY REGION AND STATE 72
5.5.1 Regional Overview 72
5.5.2 Statewide Overview 74
5.5.3 Percentage of Employees In Manufacturing 75
5.6 INDUSTRIES SELECTED FOR STUDY 79
5.6.1 The Metalworking Sector 79
5.7 REGIONAL DISTRIBUTION OF METALWORKING EMPLOYEES 79
5.8 REGIONAL DISTRIBUTION OF WAGE RATES 84
5.9 OCCUPATIONAL BREAKDOWN OF METALWORKING OPERATIVES 86
5.10 CLASSIFICATION OF JOBS BY SKILL REQUIREMENTS 86
5.10.1 Physical and Mental Requirements 91
5.11 ASSESSMENT OF POTENTIAL ROBOTICS APPLICATIONS AND ROBOT CAPABILITIES 93
5.11.1 Description of Survey 93
5.11.2 Comments on Surveys 96
5.11.3 Results and Analysis 96
5.11.4 Prime Candidates for Robotization 98
5.11.5 Estimates of the Number of Operative Task Robots Could Do 100
5.11.6 Conclusions 102

6. SHORT TERM TRANSITIONAL ISSUES 109

6.1 INTRODUCTION 109
6.2 A DESCRIPTION OF A MODEL OF LABOR FORCE CHANGE 109
6.2.1 DYNAMIC ELEMENTS 110

6.2.2 Possible Outcomes for the Labor Force 111
6.3 THE ROLE OF UNIONS 112
6.3.1 Relevant Contract Clauses 114
6.4 CHANGES TO THE UNION AND THE WORK FORCE 115
6.5 THE UNION OPTIONS 117
6.6 CONCLUSIONS 118

7. HUMAN RESOURCE POLICIES 121

7.1 INTRODUCTION 121
7.2 THE ROLE OF RETRAINING IN THE ECONOMY 121
7.3 RETRAINING IN INDUSTRY 122
7.3.1 General Policies 122
7.3.2 Non-Profit Training Institutions 123
7.3.3 Monetary Assistance 124
7.4 COMPREHENSIVE EMPLOYMENT AND TRAINING ACT--CETA 125
7.4.1 Goals and Programs 125
7.4.2 Private Sector Initiative Program 129
7.4.3 Case Study of Pittsburgh PIC 130
7.5 VOCATIONAL TRAINING 133
7.6 JOB CREATION BY ROBOTICS 134
7.7 CONCLUSION 136

8. APPENDICES 139

I. APPENDIX A INDUSTRY POLICY SURVEY 141

II. APPENDIX B INTERVIEW TRANSCRIPTS 145

III. APPENDIX C SUPPORTING DATA FOR CHARACTERIZATION OF ROBOTS AND MANUFACTURING JOBS 161

III.1 DISTRIBUTION OF EMPLOYMENT BY SIZE OF FIRM 161

IV. APPENDIX D TECHNOLOGY INITIATED CHANGE MODEL 187

IV.1 PROBLEMS AND LIMITATIONS WITH EXISTING DATA 187
IV.2 FUNCTIONAL OVERVIEW 188
IV.3 MODEL SIMULATION 189
IV.4 INDUSTRY-WIDE SIMULATION RESULTS 196
IV.5 PLANT-WIDE SIMULATION RESULTS 199

V. APPENDIX E EFFECTS OF AGE DISTRIBUTION ON UNIONS 201

VI. APPENDIX F SUPPLEMENTARY HUMAN RESOURCE MATERIAL 205

LIST OF FIGURES

Figure 1-1:	ESTIMATES OF THE U.S. ROBOT POPULATION: 1970-80	4
Figure 3-1:	COMPARISON OF TOTAL COAL PRODUCTION AND NUMBER OF WORKERS	27
Figure 3-2:	CONTINUOUS MINING MACHINES IN USE	28
Figure 3-3:	PERCENTAGE OF PENSIONED ITU MEMBERS	41
Figure 3-4:	INCREASES/DECREASES IN OLD AGE PENSION FUND	42
Figure 4-1:	A COMPARISON OF ROBOT AND HUMAN COSTS	50
Figure 4-2:	PAYBACK ON PARTS-REMOVAL ROBOTS THROUGH LABOR SAVINGS	55
Figure 4-3:	RESPONDENTS TO SURVEY AND INTERVIEWS	61
Figure 4-4:	PROFILE OF SURVEY RESPONDENTS	63
Figure 4-5:	BREAKDOWN OF ROBOT POPULATION BY EXPERIENCED AND NEW USERS	64
Figure 6-1:	UNION CONTRACT CLAUSES RELEVANT TO THE INTRODUCTION OF NEW TECHNOLOGY	116
Figure 8-1:	OPTIMAL FB/PB AS A FUNCION OF AGE	202
Figure 8-2:	TYPICAL CUMULATIVE AGE DISTRIBUTION FOR PRODUCTION WORKERS	203

LIST OF TABLES

Table 1-1:	THE NUMBER OF ROBOTS, PRODUCTION WORKERS AND MACHINES THROUGHOUT MANUFACTURING	5
Table 3-1:	WORK STOPPAGES IN COAL MINING, 1950-78	30
Table 3-2:	TRENDS IN METHODS IN BITUMINOUS COAL MINING [1]	33
Table 3-3:	UNITED MINE WORKERS OF AMERICA SHARE OF PRODUCTION	34
Table 3-4:	MEMBERSHIP IN ITU LOCAL 6, NEW YORK, NY and LOCAL 7 PITTSBURGH, PA	40
Table 4-1:	MOTIVATIONS FOR USING ROBOTS	48
Table 4-2:	ROBOT USAGE AT GENERAL MOTORS	65
Table 4-3:	ROBOT POPULATION AT SELECTED GROWTH RATES	65
Table 4-4:	CUMULATIVE NUMBER OF MANUFACTURING ESTABLISHMENTS BY SIZE	65
Table 5-1:	CAPABILITIES OF PRESENT AND FUTURE ROBOTS	69
Table 5-2:	Classification of Task That Robots Can Perform	70
Table 5-3:	ROBOT APPLICATIONS WITHIN THE AUTO INDUSTRY	71
Table 5-4:	CONTRIBUTION OF GNP BY MAJOR ECONOMIC SECTOR	73
Table 5-5:	EMPLOYMENT BY MAJOR SECTOR	73
Table 5-6:	DISTRIBUTION OF TOTAL WORKFORCE BY MAJOR OCCUPATION GROUP, 1979	74
Table 5-7:	BREAKDOWN OF SELECTED BLUE COLLAR WORKERS, 1979	75
Table 5-8:	REGIONAL BREAKDOWN OF MANUFACTURING EMPLOYMENT, 1979	76
Table 5-9:	THE 20 STATES WITH THE LARGEST NUMBER OF MANUFACTURING JOBS	77
Table 5-10:	STATES WITH HIGH AND LOW CONCENTRATIONS OF MANUFACTURING EMPLOYEES	78
Table 5-11:	EMPLOYMENT IN THE METALWORKING SECTOR, 1977	80
Table 5-12:	PRODUCTION WORKERS IN THE METALWORKING SECTOR, 1977	80
Table 5-13:	ESTIMATES OF PERCENT COVERAGE IN METALWORKING FOR SELECTED OCCUPATIONS	81
Table 5-14:	STATES WITH LARGE NUMBERS OF PRODUCTION WORKERS IN METALWORKING[46]	82
Table 5-15:	PRODUCTION WORKER EMPLOYMENT WITHIN METALWORKING FOR SELECTED STATES	83
Table 5-16:	AVERAGE HOURLY WAGES BY OCCUPATION BY REGION	85
Table 5-17:	OCCUPATIONAL MATRIX FOR SELECTED METALWORKING OPERATIVE CLASSES, NATIONAL TOTALS, 1977	87
Table 5-18:	A BREAKDOWN OF THE WORK REQUIREMENTS OF AN INSPECTOR	94
Table 5-19:	ESTIMATES OF ROBOT USE WITHIN THE RANGE OF WORKER COMPLEXITY LEVELS	95
Table 5-20:	ESTIMATES OF ROBOT USAGE WITHIN MAJOR OPERATIVE CLASSES	97
Table 5-21:	PRIME OPERATIVE TASKS FOR LEVEL I ROBOTS	99
Table 5-22:	Prime Operative Task for Level I Robots	99
Table 5-23:	EMPLOYMENT OF MAJOR CATEGORIES OF MACHINE TOOL OPERATORS	103
Table 5-24:	PRIME OPERATIVE TASK FOR LEVEL I ROBOTS	104
Table 5-25:	PRIME OPERATIVE TASK FOR LEVEL II ROBOTS	105

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[46] See the footnotes in Table 5-15. Some of these numbers may significantly underestimate the number of production workers in metalworking in some of these states.

Table 5-26:	SUMMARY OF PRIME OPERATIVE TASK	107
Table 5-27:	ESTIMATES OF THE NUMBER OF JOBS ROBOTS COULD DO IN ALL MANUFACTURING	108
Table 6-1:	EXTENT OF UNIONIZATION IN SIC 34 - 37	112
Table 7-1:	CETA SPONSORED TRAINING AND RETRAINING PROGRAMS	128
Table 7-2:	VOCATIONAL EDUCATION: TOTAL ENROLLMENT	133
Table 7-3:	CINCINNATI MILACRON: TRAINING FOR ROBOT MAINTENANCE AND REPAIR	136
Table 8-1:	DISTRIBUTION OF EMPLOYMENT BY SIZE OF FIRM IN THE METALWORKING INDUSTRY	161
Table 8-2:	BREAKDOWN OF SIC CODES 34-37	162
Table 8-3:	AVERAGE WEEKLY EARNINGS OF MANUFACTURING PRODUCTION WORKERS, 1977	164
Table 8-4:	STATES WITH HIGHEST AND LOWEST WAGE RATES	165
Table 8-5:	AVERAGE HOURLY WAGE BY SIC CODES, 1980	166
Table 8-6:	OCCUPATIONAL EMPLOYMENT STATISTICS SURVEY	167
Table 8-7:	COVERAGE OF OCCUPATIONAL EMPLOYMENT STATISTICS SURVEY	170
Table 8-8:	OPERATIVE EMPLOYMENT BY REGION FOR SELECTED OPERATIVE CLASSES, 1977	171
Table 8-9:	ADDRESSES OF STATE RESEARCH AND ANALYSIS OFFICES	179
Table 8-10:	DEFINITION OF WORKER COMPLEXITY LEVELS	182
Table 8-11:	QUESTIONNAIRE	183
Table 8-12:	SURVEY: CLASSIFICATION OF SEMI- SKILLED OPERATIVES	184
Table 8-13:	ILLINOIS: AVERAGE ANNUAL JOB OPENINGS, DUE TO GROWTH AND SEPARATION, BY OCCUPATION 1976-1985	190
Table 8-14:	Total Employment in Illinois, by Occupation	191

1. INTRODUCTION

1.1 ANTICIPATING THE GROWTH OF INDUSTRIAL ROBOTS

Technological change has been an ongoing process in industrial societies, almost a continuum. There have been repeated occurrences of new technologies initiating a series of events that opened up new opportunities and created new jobs, as well as displaced workers and made old skills obsolete.

Up until recently, most industrial research has focused on ways of augmenting human muscle, and increasing the mechanical power of production technologies. Examples are the development of motors, and power tools, such as continuous and long wall mining machines for underground coal mines, and farm tractors. The recent emphasis has been on increasing the intelligence of machines, without necessarily increasing their mechanical power. The most pervasive example is the digital computer itself, along with numerous other examples of computer controlled tools.

From a technological perspective, robotics technology is not really new. Industrial robots are a continuation of the trend of embedding more information into capital. From a social perspective, we should have enough experience with technological change to anticipate that the widespread use of robots in our factories will trigger changes in the composition of the work force, will create new job opportunities, and will force skill shifts and dislocations.

Today, nearly 15 percent of the work force is employed as production workers in manufacturing, but we expect that a smaller proportion of people will be employed in these types of jobs in the future. Already, welding lines within existing automobile factories are being rebuilt to take advantage of robot capabilities. Within the next few decades, entire factories will be designed and laid out for robot operatives, as opposed to human workers. Eventually, after several generations of new factories are built, almost all manufacturing operations required to produce both standardized and customized industrial products will be done by robots in conjunction with computer controlled machine tools, and transfer lines. This will take place gradually over the next 50 years.

In the era of the *factory of the future*, it seems reasonable to speculate that somewhere near three percent of our work force will be employed as manufacturing production workers.

Clearly, we are entering a transitional period. We must start to examine policy alternatives. Studies of the potential impacts of robotics on the labor force, and on the

economy as a whole, such as the ones being carried out at Carnegie Mellon are very important towards preventing social chaos as we make an essential, and, what we believe to be, a beneficial transition to further automating our production facilities.

In the long term, we must reconcile how to distribute income as the nature of work, and our sense of values, change. As the need to perform repetitive task both in the factory and in the office is reduced, people will be restructuring how they spend their work time, and reevaluating what to do with more leisure time.

In the short term, we need to address the mechanisms for dealing with people who are likely to burdened by technological changes. We need to examine the options for assisting the employed workers and the new job entrants to adjust to the impending changes in our factories in a *graceful* manner. We have found that many public and privately sponsored human resource programs are concerned about making a graceful transition, but do not know how to plan for it.

Hopefully, robotics will provide benefits for many segments of society by increasing productivity and extending our resource base. If this in fact true, it seems that many of the transient cost associated with labor displacements should be imposed on society as a whole, rather than on just the relatively narrow segment of society who do the types of jobs that industrial robots can do.

We need to anticipate the obsolescence of skills, and work out plans for dealing with the transition cost-- now, early in the game, before there is an unmanageable situation, in order that the new generation of robotics technology arrives with a *soft landing*.

1.2 A DESCRIPTION OF INDUSTRIAL ROBOTS

Robots can be viewed as machine tools which operate other machine tools. They move parts from one machine to another. They use spray painting guns and welding torches . They use special grippers to insert parts . They use measuring devices to inspect parts.

A robot is somewhat of a hybrid between a machine tool itself, and a machine tool operator. Like a machine, it can repeat the same task for prolonged periods with great precision. Like an operator, it can be taught to do new task, and can use accessory tools to extend its range of physical capabilities. As of today, it is fair to characterize a robot as being much more akin to a machine tool then to a human operator. They are valued in industry for the usual qualities of machines: untiring availability, repeatability, reliability, precision, and (relative) imperviousness to hostile environments. They do not, as yet, possess several important capabilities which come naturally to most humans: the ability to

coordinate the hand and the eye, the ability to react to unforeseen circumstances or changing environments , and the ability to improve performance based on prior experience.

Because of current limitations, today's robots are usefully employed in highly structured industrial environments where practically all of the variability and decision making can be engineered out of the workplace. Sometime in the near term future, though, they will have some sensory and decision making capabilities , which are necessary for working in unstructured and variable manufacturing environments.

Industrial robots in the United States are undergoing a virtual population explosion. Their numbers have increased from about 200 in 1970 to 3,500 in 1980, and their rate of growth seems to be accelerating. Industry's experience with robots, however, has so far been largely confined to a relatively small number of firms. At the beginning of 1981, almost one third of the U.S. robot population belonged to only six firms. Experience has also been largely restricted to a few industries. Indeed, according to one estimate more than half of the U.S. robots are being used in the auto industry (Engelberger 80a). Most of the others are being used in metal working and electronics. By all indications, the real impact of robotics has just begun to be felt.

Even with the nearly 20 fold increase in their numbers during the last decade, there are relatively few industrial robots in use throughout industry today. One might lose sight of how little cumulative experience industry has with these machines in light of the numerous robot applications articles in the popular and technical press. To put their numbers in perspective, compare the number of robots to production workers in manufacturing as of the beginning of 1980. In the auto industry, where they are most widely used, there was roughly 1 robot for every 400 production workers. Throughout *all* manufacturing, there was roughly 1 robot for every 4000 production workers. This compares to roughly one machine for every three production workers in the auto industry, and one machine for every two workers throughout all the industries within SIC 34-37.[1]

There are going to be a *lot* more robots in use in a short period of time. Today, there are somewhere near five thousand units installed. There will most certainly be a ten fold increase over the next decade, and their could reasonably be a fifty fold increase. Even more than a fifty fold increase in the next decade is not inconceivable.[5] As the technical capabilities of robots improve, and, -- more important-- as knowledge of how to utilize robots grows, they will be used more extensively in areas where they have already proven effective, and they will be used in many new areas.

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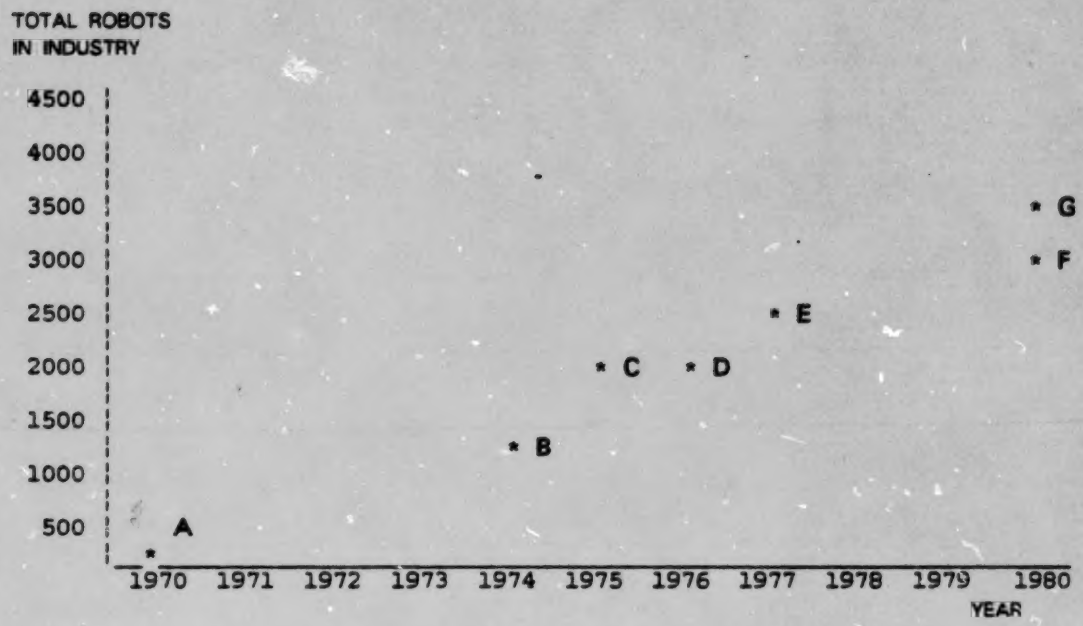
[1] SIC stands for Standard Industrial Classification.

[5] If this seems unreasonable, simply count the number of manufacturing establishments in the country today.

Figure 1-1: ESTIMATES OF THE U.S. ROBOT POPULATION: 1970-80



Point	Year	Number of Industrial Robots	Source
A	1970 (April)	200	(Engelberger 70),page 7.
B	1974 (Dec.)	1200	Frost and Sullivan, U.S. Industrial Robot Market, 1974
C	1975 (Dec.)	2000	Frost and Sullivan, The Industrial Robot Market in Europe, 1975
D	1976(Dec.)	2000	(Eikinox 79), page 164.
E	1977 (Dec.)	2400	(Eikinox 79), page 164.
	1980 (Jan.)	3000	Walt Weisel, Prab Conveyors
F	1980 (Dec.)	3200	General Motors Technical Staff (Bache, Shields Estimate)
G	1980 (June)	3500	Upper Bound Set by Business Week in (Business Week 80) Verified by Cincinnati Milacron
	1980 (Dec.)	4000	Walt Weisel, Prab Conveyors
	1981 (Dec.)	5500	Marketing Dept, Seiko Inc.

Table 1-1: THE NUMBER OF ROBOTS, PRODUCTION WORKERS AND MACHINES THROUGHOUT MANUFACTURING

	MOTOR VEHICLES AND EQUIPMENT (SIC 371)	METALWORKING (SIC 34-37)	ALL MANUFACTURING (SIC 20-39)
Estimated number of robots[2]	55% of 3500= 1925	3500	3500
Number of production workers (1979)[3]	760,000	5,705,000	15,010,000
Number of of machines[4]	238,500	2,973,600	N.A.
Workers\Robots	395	1,630	4,290
Workers\Machines	3	2	N.A.

[2] Engelberger claims that over 55 % of robots used by industry are used in building automobiles. See (Engelberger 80a), page 1. We assume all other robots are used in the metalworking sectors, SIC 34-37.

[3] Source: (Statistical Abstract 80),Table 692

[4] Source: (AM 78),page 136-137. Figures for SIC 371 collected in 1977. Figures for SIC 34-37 collected over 1976-1978. Includes metalcutting machines, metalforming machines, joining equipment, and other equipment. Sixteen hundred robots are included in this count, too.

1.3 ROBOTS AND ECONOMIC GROWTH

There are several types of benefits associated with robotics that will accrue to society as a whole, and which justify an investment by society as a whole to insure these benefits are fully achieved.

From the producers viewpoint, the major benefits to be expected from industrial robots are reductions in direct labor requirements, and improvements in the utilization of capital and materials. These benefits can be described as *factor saving*. Improvements of this type allow manufacturers to produce more with less, so to speak. The same number of products can be made with fewer production workers, or a larger output can be achieved with the same number of machines tools.

In the short run, then, robotics will help improve productivity by reducing manufacturing cost.

Producing goods and services more efficiently also yield important benefits to individuals like ourselves. Increasing productivity is a hedge against increases in input cost, and helps keep prices down in inflationary periods. Increasing productivity is also one of the keys to increase income per capita.

Further automating the factory has the potential for improving the quality of work-life. This is certainly a social benefit, even though it admittedly has a negative side. Throughout human history (and continuing today), society has functioned, in part, by forcing very large numbers of people to perform dull, dirty, dangerous, and/or demeaning but necessary task. Machines have gradually eliminated many of the worst of these task over the past two centuries. For example,in industrialized societies, humans no longer plant, cultivate or harvest crops by hand. But traditional factories still use humans for many repetitive materials handling, machine loading/unloading, tool operating and parts assembly task.

These task, in general, make use of elementary motor skills and the natural eye-hand coordination of humans without requiring either intelligence, judgement or creativity. Being repetitive, they are inevitably boring. To the extent that such tasks involve manipulating heavy workpieces, high temperatures, the use of high speed tools or reactive chemicals, there is also inherently some degree of hazard. In the long run it can only be counted as a societal benefit if such task are taken over by machines, notwithstanding the fact that such task currently provide employment and wages for a number of unskilled and semi-skilled people who ar unprepared by education or training to undertake more demanding kinds of work.

In the long run, industrial robots may also yield a very different type of benefit. They may allow us to explore and utilize the resources found under the earth, in the oceans , and in outer space. These types of benefits, described as *resource extending*, offer the potential for dramatically extending the resource base on which industrial society depends.

Already, a large fraction of U.S. petroleum production originates from offshore fields. Exploratory drilling is taking place in deeper and deeper waters. The deep oceans will almost certainly become a major source of certain metals within decades. Similarly, the economic use of space already exist and more space based activities will be on the way soon, now that the space shuttle is operational.

But deep oceans and outer space are hostile environments for humans, requiring expensive life support systems. At present, it is not economically feasible to work in these environments , except on an experimental scale. But robotics offers by far the most promising potential for future breakthroughs. Thus the opening of real "new frontiers" under the sea or in space for economic development- and ultimately, for other human uses- will only follow in the footsteps of forthcoming developments in robotics technology as applied , initially, in terrestrial situations, beginning with industrial robots in our factories.

There is a bridge between *factor saving* and *resource extending* functions. Building capable, adaptable and autonomous vehicles which can explore new worlds requires that we build new pieces of hardware, and new tools to build this hardware, and new tools to build the tools, and so on. Successful implementation of robotics and Computer Aided Manufacturing would save cost in manufacturing what is currently made,as well as reduce the cost of creating *new wealth* itself, by reducing the cost of creating new machines, new products, and new opportunities.

1.4 SOCIAL COST

It must be recognized, however, that there *are* social cost to be born as we accelerate the use of so called "intelligent" automation such as robots.

To restate the obvious: factor saving benefits are only realized when inputs are indeed conserved. Reducing direct labor requirements means displacing hourly workers. Increasing machine utilization increases the output per worker, and per unit of capital , allowing the firm to expand its production without hiring more workers. Or it can meet its current demand with fewer workers. In essence, for industrial robots, and other types of computer controlled machines to have a major impact on improving productivity, their installation must be accompanied by adjustments in the work force.

In the short term, we can predict there will dislocations. However, dislocations are by no means synonymous with massive layoffs and unemployment. It is fair to say, however, that these adjustments will lead to several different types of displacement, some being desirable, and others being burdensome.

When a robot welder is installed in a factory, the human welder may be "displaced" from his original job to another one which could not be done with a robot. He may retire, depending on his age and experience. He might be retrained to operate the robot welder. He could even be "displaced" to another industry, possibly a growing one benefiting from the surge in demand for computer controlled equipment. Of course, he could also be laid off, or retired early, and remain permanently unemployed. Thus, displacement covers a broad range of possible transitions, including in-plant or skill shifts, voluntary or involuntary separations, retirements, and lay offs.

1.5 TRAINING AND RETRAINING ISSUES

Both unions and government must play a central role in guiding this transition, but industry can not sit on the sideline. Industry has both the knowledge and management skills that are essential to success. For example, long range planning of employment requirements and identification of vulnerable job categories cannot be carried out by government agencies ,such as The Bureau of Labor Statistics , without inputs from industry.

1.5.1 The Roles of Government and Industry

It is perhaps tempting for businessmen to say, in effect, "yes, some problems may arise, but responsibility for solutions is the domain of society as a whole--which means government." At the same time, businessmen are complaining that the hand of the Federal Government already lies too heavy on business. Meanwhile, the Federal government is attempting to leave more of the responsibilities, and cost, to the individual states. It is by no means certain that the north central and northeastern states, in particular, will have the financial resources needed to provide relief on a significant scale.

In any event, the "band-aid" approach to social welfare problems has not proved especially effective in the past.

The only realistic alternative to band-aids is some sort of preventive medicine. To effectively prevent social traumas due to rapid introduction of robotics--without impeding technological progress itself--means preparing the workers most likely to be affected for changes to come . This means:

- Long range planning by industry for future employment requirements, by job skill and location.

- Identification of vulnerable categories of workers well in advance of actual job elimination.
- Provision of effective retraining facilities to upgrade workers form skill categories that are in surplus supply to skill categories that are scarce.

Since private industry, the Department of Labor, public education, and non-profit institutions have all taken some responsibility for training and retraining in the past, it is curious why very few of these entities are pushing forward, preparing for the increased use of robots. Maybe the information that pertains to the subject of robots has been mismanaged. Perhaps it has not been taken seriously enough.

A large amount is know about the types of task robots are currentably able to perform. Industry has devoted considerable resources to this specific question. Yet CETA programs and vocational schools seem to be training too many people for some of these same skills.

The public sector could play a key role in solving this information failure. An effort must be made to coordinate and disseminate available information. The public sector must take the initiative to act as information dispenser as well as trainer of those people who are not dealt with by the private sector. The private sector must play a more cooperative role with the federal government in determining what skills are to be taught. Finally, the individual must take responsibility for making use of the programs offered in both public and private sectors.

How much retraining and relocation assistance should be provided for displaced workers? And who should provide it ? These are clearly matters for public discussion and negotiation among the parties--including government. If the average citizen taxpayer receives real benefits form robotics, in the form of increased economic productivity, he will probably be willing to lend a hand , through his taxes. Workers, too will be tolerant of change if they can look forward to eventually upgrading their skills and their jobs. Industry, with the most to gain from a smooth transition, should take the led in developing an institutional mechanism to ensure it.

2. EXECUTIVE SUMMARY

2.1 TECHNOLOGICAL CHANGE IN UNDERGROUND COAL MINING AND NEWSPAPER PRINTING

The purpose of beginning the report with historical case studies is to give an overview of what types of adjustments have been made in the recent past by workers, unions, and firms in response to the rapid diffusion of labor saving technologies. In underground coal mining, and newspaper printing, management perceived new technology as a means to achieve a more competitive position with respect to substitutes that were growing in importance in the marketplace. The continuous miner and computerized typesetting diffused rapidly throughout their respective industries. In both cases, the technological change resulted in higher output per worker, a smaller work force, and the emergence of new job skills.

The policies adopted by the United Mine Workers of America (UMWA) and the International Typographers Union (ITU) in response to rapid technological change differed sharply. In a sense, the UMWA emphisized the viability of the union more than the security of the individual worker. The ITU's policies had the opposite emphasis. They bargained for job security for the worker to the point where it almost threatened the industry and the union itself.

These examples are intended to illustrate the range in union policies that have been followed in the past, and to show how these variations resulted in different types of impacts on the unions themselves, the workers, and the industries. While there are issues illuminated in each case study which may be relevant to future policy planning, there are some important differences between the unions discussed, and the unions representing the workers in the industries using robots. For example, it has been brought to our attention that the pension structure of the unions who represent workers in the metalworking and electronics industries differs quite sharply from the pension structures of both the UMWA and the ITU.

Despite the differences in policies adopted by the two unions, and differences in outcomes, the institutional structure of both unions was significantly transformed as they adapted to changes in skill shifts and declines in their membership base. Assumptions about the impact of technology on the work force which had guided earlier policies toward technological change sometimes proved wrong. For example, the ITU had always assumed that new cost saving technology would help increase demand for newspapers, and that displaced workers would be hired to meet new output levels. This was in fact the case until computerization.

2.2 THE INTRODUCTION OF ROBOTICS INTO INDUSTRY

2.2.1 Methodology

In order to gauge industry's experience with robotics, a field survey and interviews were conducted. During the Winter and Spring of 1981, project members conducted a survey of the 124 firms belonging to the Robot Institute of America (RIA). Thirty-eight firms had responded to the survey by May 1, 1981.[6] Of the respondents, 19 are currently using robots, while the remaining 19 are now considering adoption. Thirty-one interviews were also conducted. Some of the interviews were conducted primarily to follow up on questionnaires that were received. Others collected information from those who were not part of the RIA sample. The pooled sample of questionnaire respondents and those interviewed had approximately 1260 robots currently in use, nearly one-third of the U.S. robot population as of January, 1981.

2.2.2 Reasons For Using Robots

Survey respondents *overwhelmingly* ranked efforts to reduce labor costs as their main motivation for installing robots. Many of the respondents who were interviewed suggested that the heavy emphasis on direct labor savings was imposed by the methods of financial analysis used to evaluate robot applications. Almost all the firms interviewed based their decisions to use robots on a financial analysis of costs and benefits. One user pointed out that the Return on Investment (ROI) calculation will not be favorable unless there is a dramatic decrease in direct labor costs. He added that arguments about improving product quality or increasing production flexibility were nebulous, and did not carry as much weight with the financial people as direct labor savings. Given that financial analysis requires short term payback, or high ROI, it is understandable that there is such a heavy emphasis on direct labor saving. Aside from increased output, it is the only variable that is quantifiable in a straightforward fashion.

2.2.3 Quantifiability of Robot Benefits

Robots can yield many benefits in addition to direct labor savings,e.g. product quality improvements, increased throughput, better worker satisfaction, reduced indirect material requirements, increased reliability in production, and increased production flexibility. Our interviews indicate however, that most firms do not attempt to quantify "indirect" benefits in their financial analysis of the robot. Apparently, these types of cost are too difficult to

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[6] Additional responses have been received but have not yet been tabulated.

measure. Prospective users have difficulty calculating the value of indirect benefits before they have a historical record of cost savings. Direct labor savings, on the other hand, are relatively easy to quantify by using the direct wage rate and standard overhead factors.

The question was raised as to whether experienced users *learn* how to quantify "indirect benefits" as they accumulate experience with using robots. An executive at one firm speculated that inexperienced users only take direct labor cost into account because they do not know what other categories of cost will be affected. He said that his firm had learned how to quantify other indirect benefits such as improved product quality and reductions in indirect material requirements. Other experienced users did not report this kind of "learning". Thus, there are differing opinions among experienced users as to whether the analysts *learn* how to quantify indirect benefits as they gain additional robot experience.

Broader strategic concerns such as long term competitivness apparently are considered, yet they are seldom mentioned as the most important motivations. Only one firm said outright that they had invested heavily into robotics to improve the quality and the competitive standing of their product. They were also the only firm to give strong emphasis to other intangibles such as improved production flexibility. Interesting enough, this spokesman was the only person among all those interviewed to say that applications were not evaluated primarily on ROI or payback period.

2.2.4 Organizational Adaptations

With the introduction of robotics, organizations have had to make several adaptations--some to facilitate the introduction of the new technology, others to allow its effective use. Steps are generally necessary to gain the acceptance of robots by the workers. Operatives must be retrained and provisions for their safety must be made. Changes in organizational structure and managerial duties are often found to be desirable. Sometimes the production process is substantially modified to take advantage of the new capabilities offered by robots.

2.2.5 Trends In The Use Of Robots

In addition to collecting information on the current state of industry's experience with robotics, our questionnaires and interviews were also designed to elicit information on trends that may be developing. We were particularly interested in what changes had occurred with respect to the industries in which robots are used, the extent to which the increase in the robot population was due to increased usage by firms that were already using them as opposed to diffusion to new firms, changes in the production batch size of

firms using robots, and changes in the size of the establishments using robots. Accordingly, we asked respondents for information about their robot usage in 1976, in January 1981 and their projected use in the near future.

Our data suggests an expansion in the applicability of robots, from large firms to smaller ones and from mass production to custom and batch production. Several of the early large users were auto makers engaged in mass production. Later entrants among the large firms included aerospace firms engaged in custom production. Smaller firms in our sample, primarily capital goods manufacturers, also have started using robots or plan to do so.

An important question is the degree to which robot use will remain concentrated within a relatively small number of firms. It is clear that the use of robots is spreading rapidly within a small number of firms where they are well suited to production process. On the other hand, a growing number of firms are also purchasing one or a few robots to evaluate them in a new environment.

Robot use among some of the experienced users will continue to increase at an accelerating rate. Equally significant is their estimate of the anticipated shift in robot applications. For example, the percentage of robots used for assembly jobs is expected to increase, while the percentage of robots used for welding jobs will probably drop.

Estimates by financial analyst and by industry spokesmen predict a constant growth rates ranging between 30 and 60 percent per annum for worldwide sales of robots over the next decade. These growth rates may seem large, but they are indeed plausible. Assuming 3500 robots at the beginning of 1980, a constant growth rate of 50% would result in over 200,000 robots in use by 1990. There are nearly 11,500 establishments within metalworking alone with 100 or more employees. Assuming the number of establishments remains roughly constant, an average of 18 robots per establishment could absorb all 200,000 robots. As our survey indicates however, robot usage is expanding outside the metalworking industry. Given that there are nearly 38,500 establishments with 100 or more employees in all manufacturing, an average of six robots per establishment would be required to absorb all 200,000 of them. An average of six robots for every establishment with over 100 employees is not an outlandish possibility.

2.2.6 Retrofitting vs New Plant Installations

Three fourths of all users said that all of their robots had been retrofitted into existing plants, though this includes a few instances where robots were put on a new production line in an old plant. We can only speculate as to why most users are retrofitting robots, despite acknowledgements that their effectiveness is often limited by space constraints and

by limitations in other types of equipment, or processes. Our informal observations suggest that users are still trying to learn how and where to use robots. This may well be a more reasonable strategy than rushing to build new robotized plants when one considers how few people know how to design and lay out a plant that is optimized for robots, as opposed to humans.

2.3 CHARACTERIZATION OF ROBOT CAPABILITIES AND MANUFACTURING JOBS

It appears that much of the cost that may result from the increased use of industrial robots will fall on a relatively narrow segment of society- namely semi- skilled workers in the "operative" category. As it happens, these workers are relatively concentrated geographically and industrially. Many of them are physically located in the north central and northeastern part of the U.S. and belong to one of several large industrial unions representing the auto workers, the electrical workers and the machinest.

2.3.1 Impacts on Great Lakes States

Almost one quarter of all manufacturing jobs are concentrated in the East North Central region (Ohio, Indiana,Illinois,Michigan and Wisconsin). In these states, manufacturing accounts for a large number of jobs, as well as a high percentage of total statewide employment.

At present, almost all industrial robots are used within a subset of the durable goods producers commonly referred to as the *metalworking sectors.* These include[7] the following industries (followed by their Standard Industrial Classification Code):

- Fabricated Metals (SIC 34)
- Machinery except Electrical (SIC 35)
- Electrical and Electronic Equipment (SIC 36)
- Transportation Equipment (SIC 37)

2.3.2 The Metalworking Sector

The four industries cited above comprise more than one-third of the nations total manufacturing jobs , and more than one-third of the nations total production workers. More important, nearly half of all operatives jobs-- including 90 % of assemblers and nearly 70 % of machinest-- are concentrated within these four industries.

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[7] A more complete designation of the metalworking sector would include metal furniture (SIC 25), primary metals (SIC 33), precision instruments (SIC 38) and miscellaneous manufacturing industries(SIC 39). Throughout the rest of this report, we restrict our definition of the metalworking sector to SIC codes 34-37.

More than 50 % of the production workers in each of these four industries are localized within the five Great Lakes States plus New York and California. Within these same states, the metalworking sector also employees a large percentage of total manufacturing workers. Almost 70 % of the production workers in Michigan, and nearly 50 % of the production workers in Indiana, Wisconsin, and Ohio are concentrated in metalworking.

2.3.3 Prime Candidates for Robotization

We have singled out several occupational titles which have a high potential for robotization, based on the results of a survey we recently put out.[8] These occupational titles are subdivided into two categories:

- Prime operative task for Level I robots (Today's commercially available robots, which do not have sensory input)
  - Production Painters
  - Welders and Flamecutters
  - Machine Tool Operators
- Prime operative task for Level II robots (Robots with rudimentary sensors,including some degree of vision, and/or tactile and force sensing)
  - Assemblers
  - Inspectors
  - Filers,Grinders and Buffers
  - Packagers
  - Heat Treaters
  - Electroplaters

2.3.4 Estimates of the Number of Operative Task Robots Could Do

Knowing both the general types of task which robots can do, and the number of manufacturing workers who do these types of task is still not sufficient for roughly approximating the number of operatives that *potentially* could be replaced by robots. The missing variable is a realistic estimate of the extent to which robots could be used within a given job situation. We have gathered these types of estimates, and have emphasized the

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[8] This is by no means an exhaustive list. For example,several important robot applications such as loading and unloading die casting machines were not included in the survey. This is due to oversight. Occupations such as dip platers, sandblasters/shotblasters and etchers/engravers also had high estimates, but were not singled out since relatively few people do these types of jobs.

their somewhat crude and approximate nature. Acknowledging the limitations of the data, we still feel it is reasonable to use these results to weight occupational employment data on the state and national level in order to estimate the potential for robotization by occupational type. We feel the justification for publishing such preliminary estimates is the absolute lack of useful information that is publicly available on the subject.

Our estimates suggest that Level I robots could perform roughly 16 percent of the jobs within these nine occupations This could range between 8 and 32 percent.

The estimates also suggest that roughly 40 % of these jobs could be replaced by Level II robots. This could range between 20 and 80 percent.

2.3.5 Conclusions

Nearly 7% of the total work force do the types of jobs which currently are, or soon will be, in the domain of industrial robots. But robots can not do all of these task in the foreseeable future, especially, if they are retrofitted into existing facilities. More realistically , robots which are commercially available today could possibly perform nearly 16 percent of the operative task within those manufacuturing industries where they are well suited (with estimates ranging between 8 and 32 percent), and sensor based robots could possibly perform nearly 40 percent of these operative task (with estimates ranging between 20 percent and 80 percent). In the short term, maybe as many as two percent of the entire work force could possibly be replaced by robots. With the next two decades, maybe this number will increase to four percent, possibly to seven percent. This is hardly catastrophic on the national scale, especially when one allows for new job opportunities. But adjustments made in response to the rapid diffusion of this new technology are likely to be intensified in those geographic regions, such as the Great Lakes states, the northeastern states, and California, where manufacturing operatives are concentrated.

2.4 SHORT TERM TRANSITIONAL ISSUES

2.4.1 Introduction

Some of the workers who may be displaced as a result of robotics will be retrained or transferred to other jobs within the firm, others will be scheduled for early retirement, and still others will be laid-off due to job eliminations and decreased manpower requirements. The nature of the transition will depend on a variety of factors, including the magnitude of worker displacement, the ages of the workers, the ability of the economy to reabsorb workers, the rate of introduction of robots,and the mechanisms which will guide the

transition. Although we cannot account for the effects on individuals, we can discuss the aggregate aspects of the transition.

2.4.2 Possible Outcomes for the Labor Force

The end result of the introduction of the new technology is a redistribution of the original stock of workers among the following possible alternatives:

- retirement:
  - normal retirement: for those of the proper age and qualifications;
  - voluntary early retirement: for those who meet certain age and service qualifications, but do not fall under the coverage of normal retirement;
  - special early retirement: for those who are given the choice to leave the work force earlier than normal without benefit penalty.
- Retention:
  - transfer horizontally: workers who are laid off,either temporarily or permanently;
  - transferred vertically: workers who are moved to other jobs/departments within the plant;
  - retraining: a subset of those transferred horizontally who will have to be retrained to learn how to operate new machinery.
- voluntary quitting: Some workers may elect to find other employment if the are disgruntled with the changes on the job;
- lay offs: Lay offs can be permanent or temporary. If permanent, workers have no recourse or guarantee of future employment. Temporary lay offs provide workers the option to be rehired on the basis of seniority, skill-level, and job class.

2.4.3 The Role of Unions

One of the major mechanisms which affect worker assignments to the range of alternatives are union contracts. Over 90% of the workers in the metalworking sector (SIC 34-37) are covered by some sort of union collective bargaining agreement. We can expect that unions and union membership will be heavily involved in the mechanics of the transition to robotics. Although we could not gather information which cross classifies workers by SIC code and specific union membership, it appears that the main unions organized in the metalworking industries are:[9]

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[9] This list does not include all the unions in these industries.

- United Automobile, Aerospace and Agricultural Implement Workers of America (UAW)
- The International Brotherhood of Electrical Workers (IBEW)
- The International Association of Machinists and Aerospace Workers (IAM)
- The International Union of Electrical, Radio and Machine Workers (IUE)

Unions have seldom opposed the introduction of new technology as long as the benefits brought about by this technology are shared with their members. Through negotiations with management, unions have been able to increase wages and fringe benefits, improve working conditions, and insulate workers against lay-offs and other cutbacks.

Collective bargaining contracts are the formal mechanism that unions use to affect company policy. Through contract negotiations unions are able to influence company policies as well as their own job security and compensation rates. Union contracts are marked by their large number and the diversity of their provisions and sphere of influence.

2.4.4 Relevant Contract Clauses

Several contract clauses relevant to the introduction of new technology identified from the four union contracts we surveyed are:

- Paid Personal Holidays (PPH): increases wages while decreasing work time by giving workers more days off with pay (in addition to standard holidays). For example, the UAW has negotiated twenty-six Paid Personal Holidays for each member over a three year period. In the event of possible worker displacement, reduced work time redistributes the available jobs to a greater number of workers. The intent is to reduce the number of workers laid off. Other unions have implemented similar plans by increasing the standard vacation time. These policies may reduce potential loss to union of membership. On the other hand, they definitely increase the firm's labor costs without increasing input.
- Supplemental Unemployment Benefits: used in addition to unemployment compensation to aid workers through lay off periods. Nationally, the UAW is the principal advocate of this program.
- Transition Allowances: provided to workers when the firm transfers employees from plant-to-plant. These allowances range from $500 to $1760 in the contracts we looked at. In some cases benefits will also follow the employee from plant-to-plant. Seniority does not transfer for the IAM.
- Advance notice of technological change: required in all four of the reviewed contracts. The extent of union input into such a change varied from union to union. The UAW and the IAM have committees consisting of both union and management representation which would study and discuss each change in technology, whereas, the IBEW contract indicates that the company retains the sole right of deciding the introduction of new technology.

- Severance Pay: used to provide for workers who are permanently laid-off. It effectively pays workers to leave their jobs. Severance Pay is often used in cases of special retirement,where workers are paid lump sums to leave the job and in addition, receive a percentage of their original pension benefits. This plan has the advantage of easing pressures on the union pension fund. It also provides the firm with a quick,but very costly means of reducing the size of the work force.

- Retraining Provisions: Three of the four unions studied have negotiated retraining provisions as the responsibility of the employer. By accepting the cost burden, the employer has shown an interest in allowing the employee's skills to improve along with technology. The IUE has stated that it will make available specialized training for qualified workers displaced by new technology. Such a provision would make it possible for some displaced workers to be trained in the supervision or maintenance of robots which had originally replaced them. However not all displaced workers can be reabsorbed in this way.

- Sharing of Increased Productivity Benefits: are the result of improved technology providing increased productivity and in turn increased corporate profits. By sharing the increased profits with the union, the company improves the acceptance of new technology in the work place. The UAW's Wage Improvement Factor was the only example of shared increased productivity benefits found in the contracts studied.

2.4.5 Conclusions

Both unions and management have a difficult task: to protect affected workers in the short run without raising production costs enough to jeopardize the existence of the plant in the long run. Each side must take into account the other's needs and constraints. Management must be aware of the social and personal costs to workers faced with unemployment. Unions must be aware of the effect of the wide use of high-cost benefits on the firm's cost function.

There exists a series of possible events which could seriously affect both unions and management. These events could occur as follows:

1. American industries face increasing competition from foreign markets. Because of this competition, industry is forced to continually modernize its production process. One important aspect of modernization is robotics.

2. As industry improves its production process, workers will be displaced in the short run. Such worker displacement involves a large cost to both the displaced workers as well as to society as a whole. The trauma and financial problems associated with being laid-off are clearly evident to the unemployed worker. Society also pays a cost through factors such as increased unemployment compensation payments and a shrinking work force.

3. Unions will then attempt to provide for the displaced workers. They will achieve this through concepts such as Paid Personal Holidays, Special Early Retirement, and Relocation Allowances.

4. As the cost of labor is increased, capital expenditures become more financially attractive. When the increased cost of labor is combined with the industry's need to compete abroad, the firm has no choice but to increase the amount of capital used. In effect the unions might price themselves out of the market.

Industry will suffer if they are unable to modernize. Unless they do so, some firms face a realistic threat of losing their markets to other (often foreign) producers who have already upgraded their facilities with robotics or with other types of computer controlled production technologies. Unions, and individual workers will also suffer if firms fail, because union members will lose jobs. We conceivably could face a dilemma where the unions are faced with either losing some jobs due to robotics or all the jobs as a result of firm failure. However, improving the productive capabilities of the economy through modernizing would inevitably create new opportunities, although it is hard to predict what they are, or where they might be.

We have three recommendations for fostering a cooperative climate between industry and unions:

1. Joint union–management committees should be formed. These committees would provide advance notice to the union leadership of an impending technological change. With this knowledge unions will be in a better position to adequately provide a smoother transition to the presence of improved technology.

2. When providing for potentially displaced workers the age distribution of the affected worker population should be considered. The age distribution can dictate the proper alternative for the method used to provide for the displaced workers. For example, if worker age distribution is skewed toward the regular retirement age, early retirement becomes the best solution. However, if the age distribution is skewed noticeably younger, then other alternatives such as retraining or severance pay need to be considered.

3. Some methods of providing for the displaced workers entail a high cost while others entail a low cost to the firm. A high cost method would be one that increased wages while simultaneously decreasing work time. Examples of high cost methods include Paid Personal Holidays, increased vacation time, and in some cases Special Early Retirement. A low cost method would include provisions such as retraining or in most cases severance pay. Unions should be willing to accept and utilize the lower cost methods in providing for its displaced workers.

In the past, labor and management relationships have typically been adversary in nature. Given the current economic situation of American manufacturing industry, this adversary relationship is giving way to a more cooperative one. We believe that if the transition to robotics is to occur smoothly, this cooperation *must* continue.

2.5 HUMAN RESOURCE POLICIES

Retraining is important from both the viewpoint of the employee and the employer. The employee views retraining as any training which takes place after his basic education and his first job training is completed. It is often a means to secure continued employment. Employers view retraining as a necessary means of upgrading labor productivity when new and advanced technology is adopted within the organization.

Private firms do do a great deal of retraining. However, they most frequently initiate it "on demand", i.e. after a need is recognized, as the new positions become available. They are not equipped to deal with the numbers and types of retraining which may be caused by the introduction of robotics into the workplace.

There is also a segment of the labor force whose skills are no longer needed. This includes people who have been trained but never hired, as well as unskilled entry-level employees who have been displaced. Industry retrains experienced employees to move laterally within the firm, but is not equipped or financially motivated to handle the "structurally" unemployed segment of the work force. Thus, although industry is assuming some of the responsibility for dealing with worker retraining, it cannot be held responsible for dealing with the entire problem of unemployability, especially where basic educational background is inadequate.

Education and training are established functions of government. It is vital however, that publicly funded education/training programs reflect the future-rather than the past- needs of industry and society for skills. Presently , vocational education enrollment figures available from several states and from the federal Department of Education , leave little doubt that large numbers of young people are learning welding and machine tool operations, and other types of skills which robots can do.

The effectiveness and appropriateness of current training and retraining programs have been investigated, all in terms of impending robotics. The other side of the issue is that a number of jobs will be created due to the introduction of robots into the workplace, especially in programming, maintenance, and operation. It does not appear that the number of positions created to perform these tasks will be sufficient to have any significant impact on the number of people displaced or unemployed. While it is true that the operation and maintenance of robots will create some jobs and that the appropriate skills must indeed be taught, these new jobs are not the sole answer to the social problems which may arise from the introduction of robots.

Major problems have come to light, and they can be seen as parts of two major failures: a market failure and an institutional failure.

The market failure comes about as a result of insufficient information being dispersed in the economy. Although there has been extensive research done about the future job market, little of it is known to the public--those planning the training and retraining programs, as well as the individuals. For example, a quite a bit is known about the types of tasks robots are currently able to perform. Industry has devoted considerable resources to this specific question. Yet, CETA programs and vocational schools are unquestionably training too many people for these very skills.

The institutional failure is one in which each of the training mechanisms has not properly prepared for the future needs of the economy. Even when the forecasts of future job opportunities and needs are available to them, the institutions are not reacting properly. This problem consists of a lack of two mechanisms within these institutions: a mechanism for receiving the available information, and a mechanism for acting accordingly.

CETA and Vocational schools have at their disposal quite a bit of information which they do not reach out and take. Bringing the private sector in for consultation is one mechanism by which they can receive the proper information. Attempts have already been made in this direction, as was seen in the Private Industry Councils and vocational advisory councils. The goal is to get the proper people on these panels. Involved should be people from industry, people involved with the technical advancements, people in academia, among others.

Once changes in the economy are perceived, procedures and incentives for changing the training programs must be implemented. For example, although the importance of computers has long been recognized, many of the private non-profit training centers still do not train people as programmers or operators. This institutional failure can be seen in a bureaucratic framework. The goal of the institution is ostensibly to prepare people for the work force, but the goals of the subunits within the organization are far different. These goals are simply to get people through the programs, thus having documentation of "success." The institutions are not effectively evaluating their current training and retraining programs or considering the viable alternatives. As a solution, the institutions should make explicit the goal of changing training programs with the alterations of the economy. Incentives for managers should be given to facilitate reasonable change. Strong encouragement for altering from the status quo should be given.

If solutions to the failures discussed above are actively sought, and acted upon, and a cooperative attitude prevails between the public sector, private sector, and individuals, the introduction of robotics can be a smooth and easy transition. $

3. TECHNOLOGICAL CHANGE IN COAL MINING AND NEWSPAPER PRINTING

3.1 INTRODUCTION

Early robot installations may not be indicative of what may happen to workers, the workplace, and the firm itself when the technology is widely used. Historical studies of technological diffusion, covering the full cycle from early adoption to wide spread use, may be more useful for anticipating future social impacts. Selected examples from the industries involved with newspaper typesetting and underground bituminous coal mining are presented here. Both of these industries have experienced extensive technological changes during the past decades.

Computerized typesetting systems used in newspaper printing are a *flexible* technology. Computers are capable of performing a wide range of functions, and can be adapted to perform new functions. Industrial robots share this "flexible" characteristic. The International Typographers Union (ITU), the dominant craft union in the newspaper industry, provides an example of labor and technological change coming head on. ITU locals have maintained a high degree of autonomy in the union's history. The response of each local to the introduction of computerized typesetting varied. Even so, almost all union locals shared in common the de-skilling of their craft and the adoption of re-training, attrition, and merging policies.

The bituminous coal industry in the late 1940's and early 50's underwent a massive mechanization program with the introduction of the continuous mining machine into underground coal mines. Bituminous coal mining provides an example where a labor union cooperated with, and even promoted the introduction of new technology. In 1946, the United Mine Workers of America (UMWA) signed an agreement in which automation was encouraged in return for higher wages and an operator-financed pension fund.

3.2 BITUMINOUS COAL

3.2.1 Overview of the Technology

Until the late 1940's, all bituminous coal mining was done by undercutting. A deep horizontal groove was cut into the base of the coal seam wall-- (undercutting)-- and wedges or explosives were used to bring down and shatter the face of the coal wall. The shattered coal was then loaded into shuttle cars. Originally the undercut was hewn by hand, using picks. The dangerous and labor intensive nature of this work spurred the development of mechanized undercutters in the 1880's (Statham 56).

Prior to 1900, all coal was hand loaded into tubs or carts with forks or shovels (Coal Age 61). In 1902, the conveyor was introduced. Ten years later, in 1912, the power loader was developed. The power loader automatically loaded loose coal into shuttle cars or onto conveyors. It was widely adopted throughout the industry. Before the power loader, almost sixty percent of total labor was used for hand loading. By 1949, sixty-seven percent of all bituminous coal was mechanically loaded. (Monthly Labor Review 61).

The first successful continuous mining machine was introduced into an underground mine in early 1948 (Kenner 81). The continuous miner performed the jobs of three earlier machines: the undercutting machine, the face drill (used for blasting), and the power loader.

The first and most immediate benefit of using the continuous miner was a reduction in the number of machines and laborers. Before its introduction, a work group team for a single coal face consisted of:

1 **CUTTER**--operated the undercutting machine
1 **HELPER**--assisted in undercutting
1 **FACE DRILLER**--controlled all aspects of bringing down the coal face: drilled holes, placed and set explosives
1 **LOADING OPERATOR**--operated the power loader
1 **ROOF BOLTER**--reinforced the mine walls and ceiling
1 **FOREMAN**--supervised the operation

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6 **TOTAL**

After the introduction of the continuous miner, the work group consisted of:

1 MINER OPERATOR--operated continuous mining machine
1 HELPER--assisted in operation
1 ROOF BOLTER--reinforced mine wall and ceiling
1 FOREMAN--supervised the operation
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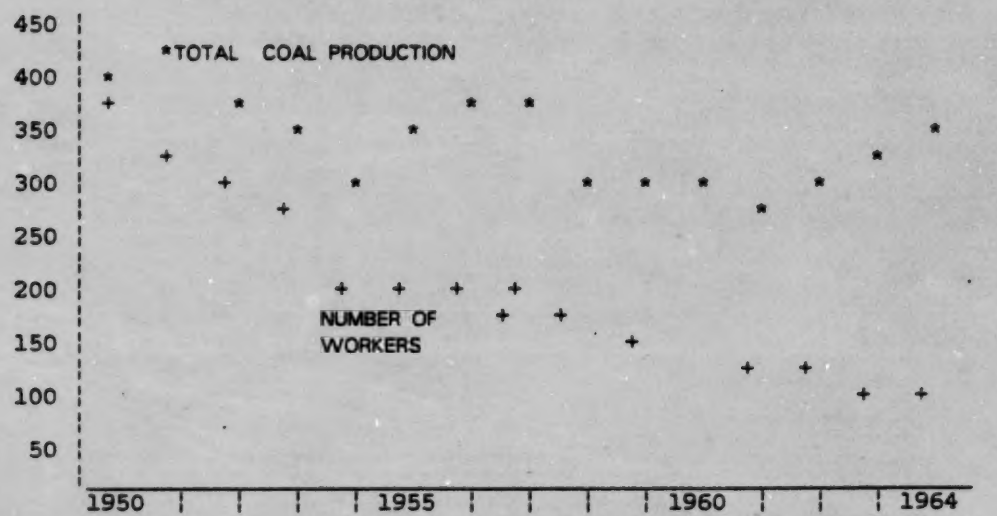
4 TOTAL

With the new technology, the four person group could produce three times as much coal as the six person group using the best equipment previously available. The huge increase in output caused problems in other parts of the mining operation. Coal handlers could not handle maximum loads of up to five tons a minute per team (Joy Bulletin 81). This increase in productivity can be attributed mainly to the introduction of the continuous miner. Figure 3-1 shows the relationship between total underground coal production and total employment in underground coal mining.

Figure 3-1: COMPARISON OF TOTAL COAL PRODUCTION AND NUMBER OF WORKERS



SOURCE: BLS BULLETIN 2072

As shown in Figure 3-1 employment in the bituminous coal industry decreased after

1950. In the period between 1950 and 1964, the number of miners declined by approximately 246,000, or 59 percent. By 1969, the number of miners declined to 125,000, the lowest level in the century.

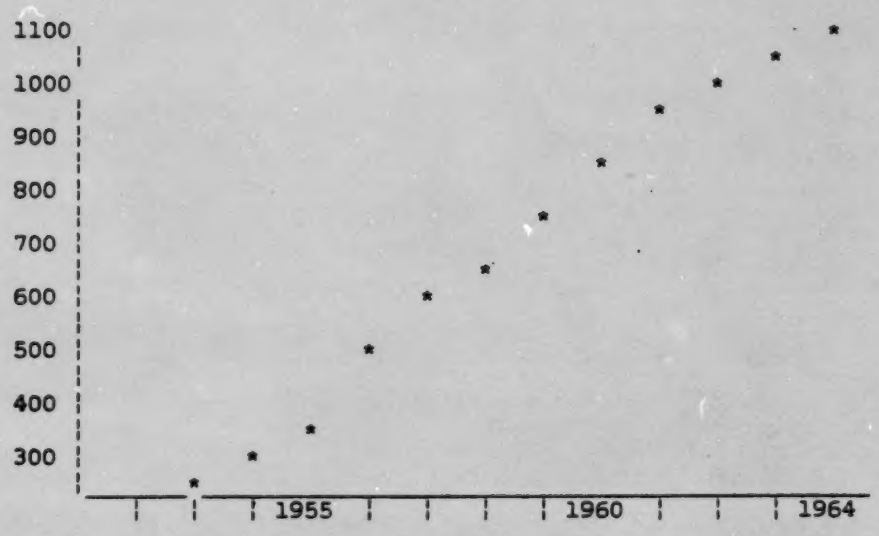
3.2.2 The Diffusion of the Continuous Miner

Mining firms would initially purchase only one or two machines. Usually, only a small section of the mine was wholly converted to continuous mining. The displaced workers were relocated to those parts of the mine using conventional techniques (Kenner 81). The continuous miner proved to be extremely efficient. More machines were quickly purchased. Within 6 months after they introduced the first successful continuous miner, Jov Manufacturing Company reported orders for 300 machines with a rapidly growing backlog (Joy Bulletin 81).

In 1950, approximately two percent of underground coal was mined with the continuous mining machine. By 1955, the proportion had increased to 10 percent. By 1960,over 25 percent of underground coal was mined with the continuous miner, and by 1970, the proportion increased to 50 percent (BLS 61).

Figure 3-2 shows how the use of these machines increased between 1953 to 1964.

Figure 3-2: CONTINUOUS MINING MACHINES IN USE



SOURCE: BLS BULLETINS NO. 1305, NO. 2072

An assessment of technological change in the bituminous coal industry should take into account the dynamics of the industry. From the late 1940's to the early 1960's, there was increasing mechanization within the mine. Coal's share of the energy fuels market was also decreasing. Residential, railroad, industrial, and utility markets shifted from coal to oil and natural gas. From the late 1960's until the present, there has been a decrease in output per worker, and an expansion of the surface coal mining.

Increases in output per worker during the period between 1950 and 1964 should be viewed against the large number of work stoppages. During this period, which spanned the Bituminous Coal Operators Association (BCOA) and the UMWA contract of 1950, there were no contract strikes, but numerous workdays were lost during wildcat strikes. The number of stoppages and number of person days lost during this period are shown in Table 3-1.

3.2.3 Requirements for New Skills

Mechanization in the bituminous coal industry has (1) reduced the labor force; (2) increased output with the same or reduced labor force; (3) generated the need for new skills and (4) required a higher level of management skills.

The use of high-technology in the mine led to new working conditions, and requirements for new types of skills. New spatial arrangements were required for workers. Face crews were concentrated in two or three locations at a section while support crews were dispersed over the length of the mine. Support personnel have grown from nearly ten percent of the total underground mining force in 1890, to fifteen percent in 1930, to almost fifty percent in the late 1970s. The growth of large support systems and high-technology mining machinery required specialized engineers and technicians to monitor and direct operations (Yarrow 79).

High-technology has also been accompanied by an increase in the number of supervisory personnel. In 1890 the ratio of supervisors to workers in underground operations was 1:100, in 1930 it was 2:100, and in 1969 the ratio was 12:100. Operators have gone from "controlling the worker to controlling the work process." (Yarrow 79).

3.2.4 Retraining

Operation of the new machines required new skills. Workers had to be retrained. To assist in the retraining, representatives from the machine manufacturers, both servicemen and demonstrators, accompanied the first machines into the mines. The instruction was done on-site. Workers were instructed on every facet of machine operation, while

Table 3-1: WORK STOPPAGES IN COAL MINING, 1950-78

Year	Number of Stoppages	Workers Involved	Person Days Idle During Year (All Stoppages)
1950	430	165,000	9,320,000
1951	549	213,000	887,000
1952	560	472,000	2,760,000
1953	392	130,000	418,000
1954	208	81,900	344,000
1955	292	77,500	273,000
1956	266	84,800	377,000
1957	161	46,400	136,000
1958	136	29,700	102,000
1959	146	64,000	1,560,000
1960	120	37,200	137,000
1961	117	25,100	90,700
1962	121	34,300	191,000
1963	131	38,000	234,000
1964	111	56,800	340,000
1965	145	62,600	258,000
1966	160	88,100	629,000
1967	207	62,900	158,000
1968	266	206,400	956,600
1969	457	206,000	900,600
1970	500	198,600	627,000
1971	606	350,700	4,215,000
1972	963	256,000	562,400
1973	1,039	289,800	559,900
1974	996	459,900	3,310,100
1975	1,139	387,200	1,501,300
1976	1,383	506,900	1,980,000
1977	958	649,800	5,628,300
1978	250	108,300	9,946,400

SOURCE: BLS BULLETINS NO. 1305, NO. 2072

maintenance was taught to the service section (Kenner 81). The manufacturers only did this type of training for the initial machines. As the firms accumulated experience, the manufacturers left the subsequent training to the mining operations. Instruction methods differed in every mine.

Mechanization increased the level of technical knowledge required to mine coal. New job skills were needed. Closer coordination was required in the mine, especially at the face, where operations are sequential. High-skill levels were required to operate a number of large, high speed machines safely in a spatially constrained, dimly lit environment (Yarrow 79).

The unity of miners as a group was apparently maintained during this period of rapid technological change. Until the introduction of the longwall mining technique, workers were able to control the speed and direction of machines. Mine workers have been able to resist control by management in the mine by: (1) monopolizing information about immediate working conditions; and by (2) controlling the speed of machines, how fast to work, how many shortcuts to take, and when to perform certain tasks or jobs. Other factors not related to technology, but unique to coal mining, also contribute to miner unity, but are not within the scope of this study (Yarrow 79).

3.2.5 UMWA Policies Toward Automation

The United Mine Workers of America has maintained a dominant role in underground coal mining, even though . the percentage of mine workers it has represented has varied since 1946. In 1946, the UMWA represented nearly 98 percent of underground workers--416,000 out of 425,000 bituminous coal miners (Miernyk 80). In 1956, the UMWA represented about eighty percent of all soft coal miners (Myers 61). In 1977, they represented ninety percent of all underground miners (UMWA 81).

The position of the UMWA toward mechanization was essentially that of its president for 40 years, John L. Lewis. He dominated union policy. He used Article III, Section 2 of the UMWA constitution to revoke charters of local districts and to suspend their elected officers. In 1948, 21 out of 31 districts had officers appointed by Lewis and known to be loyal to his views (Miernyk 80). In addition, Lewis discouraged debate at union conventions (UMW Jounral 74).

In the prewar period, John L. Lewis recognized the impact that mechanization could have on the industry. At its 1934 convention, the UMWA adopted a resolution endorsing mechanization. The report of the convention states:

> Rather than object to mechanization of industry, we should devote our efforts

> toward a shorter work day and work week, toward greater participation in the blessings of invention, of science, of progress, with a fundamental objective of making mankind the masters of their destiny and subjecting machines, science, and modern developments of industry to humankind (Miernyk 80).

At the same convention, Lewis stated that machines could give the industry and its workers a "wage produced by the machine that will maintain them and their families in comfort and with a provision for old age" (Miernyk 80).

During the 1950's, the UMWA facilitated the introduction of mechanization into the mines by loaning millions of dollars to coal companies, which Lewis encouraged, for specifically modernizing the industry. Loans were made through the National Bank of Washington, in which the UMWA gained a controlling interest in the 1950s (Hume 71).

On May 21, 1946, Lewis achieved his goal of establishing a pension fund. The creation of the Welfare and Retirement Fund was part of an agreement signed by the U.S. government and the UMWA. The agreement ended a 45 day strike by the union, during which time the government took possession of the mines under the War Labor Disputes Act. The key provision of the fund was that it was to be financed by a royalty tax based on tonnage of coal produced in those mines employing UMWA workers, as opposed to contributions based on the number of man hours or of miners employed. With this type of financing, miner lay-offs would not decrease the amount of royalties paid into the fund.

A medical and hospital fund was also created by the agreement. It provided medical and hospital services for the miners and their dependents, and was financed by deductions from the paychecks of the miners.

An event unforeseen by union leaders was the shift to surface mining, which is less unionized than the underground sector (See Table3-2). The growth of surface mining has decreases the UMWA share of coal production (See Table 3-3), which is still an important concern to the union. In recent contract negotiations, the UMWA has attempted to reinstate a royalty on non-union coal processed by UMWA companies.

The miners who who were laid-off due to mechanization were not protected in any way. Lewis reasoned that these younger miners could find employment in other industries. In an interview, Lewis is quoted as stating, "...the younger men go by the tens of thousands into other industries to get jobs." (Business Week 59). Miners working for thousands of small mines were displaced because small mine operators were unable to automate and were not involved in the "industry-wide" contract (Hume 71). Neither benefits nor retraining programs, were developed to help the unemployed miners (UMW Jounral 74).

The UMWA policy of encouraging mechanization and automation, and especially its

Table 3-2: TRENDS IN METHODS IN BITUMINOUS COAL MINING [1]

	Surface Production		Underground Production	
year	Millions of Tons	Percent of Total	Millions of Tons	Percent of Total
1950	123.5	23.9	392.0	76.1
1965	179.4	35.0	332.7	65.0
1966	195.4	36.6	338.5	63.4
1967	203.5	36.8	349.1	63.2
1968	201.1	36.9	344.1	63.1
1969	213.4	38.1	347.1	61.9
1970	264.1	43.8	338.8	56.2
1971	276.3	50.0	275.9	50.0
1972	291.3	48.9	304.1	51.1
1973	292.4	49.4	299.4	50.6
1974	326.1	54.0	277.3	46.0
1975	355.6	54.8	292.8	45.2
1976	383.8	56.5	294.9	43.5
1977	416.9	60.5	271.6	39.5
1978	410.3	62.8	243.5	37.2
1979[2]	478.0	62.1	292.0	37.9

1) Annual sums for surface and underground production may not equal total found in Table 1 due to rounding.

2) Preliminary.

SOURCES: 1950,1965-75 U.S. DEPARTMENT OF THE INTERIOR, BUREAU OF MINES, MINERALS YEARBOOK, "BITUMINOUS COAL AND LIGNITE," ANNUAL. 1976-1979 -- U.S. DEPARTMENT OF ENERGY, ENERGY INFORMATION ADMINISTRATION, ENERGY DATA REPORTS, "WEEKLY COAL REPORT."

Table 3-3: UNITED MINE WORKERS OF AMERICA SHARE OF PRODUCTION

(Millions of Tons)

Year	Total Bituminous Production	UMWA Percent Share of Production	UMWA Tons Produced
1951	534	78.5	419
1967	553	73.6	407
1968	545	72.7	396
1969	561	72.0	404
1970	603	70.3	424
1971	552	65.6	362
1972	595	70.6	420
1973	592	69.1	409
1974	603	64.8	391
1975	648	62.0	402
1976	679	58.6	398
1977	689	52.1	359

1 NATIONAL BITUMINOUS COAL WAGE AGREEMENT TONNAGE, 1951-1977, AND WESTERN SURFACE AGREEMENT TONNAGE, 1972-1977.

2 ESTIMATE BASED UPON 1951-1955 AVERAGE SHARE.

Source: BCOA.

massive financial assistance, was reversed to a more adversarial policy in 1963. The union did not consider the survival of the bituminous coal industry an issue. The then president of UMWA, Tony Boyle, felt an increase pressure from the rank and file of the union to demand job security, paid holidays, and other fringe benefits from the operators, which had been foregone since 1950. Boyle, in a widely quoted speech in 1963, stated, "This automation and mechanization has gone far beyond what Mr. Lewis was talking about when he urged the mines to mechanize." (Hume 71).

3.2.6 Summary of the Impacts of the Continuous Miner

From 1934 to 1963, the UMWA actively encouraged mechanization in the soft coal industry. Faced with the declining demand for coal, the union decided that its best strategy was to encourage , and even promote the use of new mining techniques. In return for its support of new technology, the union won a pension fund for its older miners, and increased wages and benefits for the miners still in the industry. Unfortunately, no assistance was given to the thousands of miners displaced in the process.

3.3 NEWSPAPER TYPESETTING

3.3.1 Overview of the Technology

The introduction of the linotype machine in 1886 was virtually the first important new technology in the printing industry since its inception. The linotype machine automatically cast lines of print into metal. The reporter's stories were typed, edited and sent to the composing room. At the machine, a skilled operator retyped the copy, while the linotype machine cast hot metal slugs forming single lines of type.

In the late 1940's, additional technologies found their way into the process. The "justifying typewriter" allowed an ordinary typist to replace the skilled linotype operator, since the typewriter was able to justify lines automatically. Another innovation was the teletypesetter. This device produced a punched paper tape, which directly operated a linotype machine. The late 1940's also saw the beginning of new photographic processes which replaced hot metal printing plates.

3.3.2 The Diffusion Of Computerized Typesetting

During the 1960's, electronics penetrated the industry. By 1964, there were 98 computerized typesetting facilities in the United States. In 1968, that number had increased to 663 (Zimbalist 79a). Machines were introduced which could photographically change edited stories into complete columns of justified type without any intervention of the printer. These "cold type" devices were linked with computers to form photocomposing machines capable of producing up to 150 lines per minute, as compared to 3 for a skilled linotype operator. Under the computerized system, the reporters type their stories on video terminals. Editors display the stories on their own terminals and edit them. The final version is sent back to the computer, which directs it to a cold type machine. The layout is then printed on computer-operated printing presses (BLS 73).

By the mid 1960's, the 1000 existing phototypesetting machine performed two percent of all typesetting. In 1973, 15,000 of these units were performing thirty percent of all typesetting. Conversion to cold type offset has taken place rapidly over the last thirty years. In 1979, eighty-eight percent of all newspapers had this capability (Zimbalist 79a).

Pagination is a new technology involving computerized page makeup which can render the entire composing room obsolete. The limiting factor is the ability of the computer to store the millions of dots required to reproduce pictures. However, new techniques will make the printing process useful for large newspapers within the next five years. The next step may be laser-xerographic processes which use sprayed ink systems to allow direct image formation , thus bypassing the presses (Zimbalist 79a).

3.4 THE CASE OF THE NEW YORK TIMES AND THE PITTSBURGH PRESS

The most dramatic technological change in the newspaper industry occurred in the composing room. In 1971, one-half of all printing craftsmen were employed in the composing room (BLS 73). The majority of computer typesetting installations occurred in the late 1960's and early 1970's. The New York Times conversion occurred in 1974 and by November of that year, photocomposition was used for stock reports resulting in greater clarity, accuracy and completeness. In February, 1975, display advertising was phototypeset. Photocomposition was used for classified advertisements by August, 1975. The Sunday edition classifieds, which had previously required 3 days to typeset, could now be completed in only 20 minutes. Misprints and misplacements had been frequent, due to the large number of advertisements received. Control of advertisement run length and deletion were haphazard at best. These factors resulted in revenue losses and customer-dissatisfaction. Automation has increased customer satisfaction by cutting the error rate in half, and has benefited accounting control even more (QWL 77a).

Only 25 percent of advertisement copy was processed by the new technology in 1977. The remaining 75 percent awaited more sophisticated computer programs and changes in editorial work practices. More reliable computers, as well as back-up systems will be required. By 1979, cold type had fully replaced hot type at the Times. Over 80 percent of the work had been computerized (QWL 77a).

3.4.1 Requirements for New Skills

The new technology of the past two decades has had serious implications for the typographers craft. The traditional skill requirements have become much more technical. Linecasting machine operators now serve as keypunch operators and typists. The work is described as "...more confining and monotonous than working at a linotype machine. Job printers, in particular, would be bored by the lack of variety and the limitation on the use of their skills" (Kelber 67). Journeymen typesetters, now termed assistants by the International Typographers Union (ITU), do photocomposition work, paste makeup and film processing. One make-up man at The New York Times describes the transition: "..to me it's no challenge any more... Editors used to come up and work with you..you were a craftsman..Now you paste it on the board. There's nothing to it" (Zimbalist 79a).

Jobs have become more sedentary and have been designed so that only a solitary function is performed. The The Pittsburgh Press and The New York Times have attempted to move workers among different types of jobs to curtail the increased employee alienation. At the Press composing room a print was once committed to one of eight specific functions. New technology connotes interchangeable skills, in that, the Press

employees rotate among the various tasks in the composing room. A survey of The New York Times found that "most [local 6] members would prefer to stay on a single important task than rotate through a group of less important ones." (QWL 77a)

Nevertheless, managers and employees at the Times report reduced labor costs. In the automated departments, overtime was reduced from 2,000 hours per week to only 500. In the news machine room, overtime has dropped from 1,500 hours per week to a negligible amount. The composing room staff decreased from 830 ITU employees(630 regulars, 200 substitutes) to 685 ITU employees (all regulars) (QWL 77a). The decrease in composing room employees was les drastic at Times than at other newspapers because of the strength of ITU local 6.

New occupations have been created - computer programmer, computer console operator, and system analysts, for examples. The Department of Labor reports that the industry practice in the 1960's and 1970's was to train existing staff for the programmer and operator positions. System analysts were often hired from outside the firm because of the highly technical nature of the job. The experience of the Pittsburgh Press was similar. ITU machinists continued to maintain new machinery, but the newspaper hired two men for highly technical functions and for providing training to union machinists in electronics. ITU printers write formatting programs at the Press for typesetting and advertising displays. The newspaper staff programs editorial and business material. Local 7 also had jurisdiction over the now obsolete computer console operator position.

3.4.2 Retraining

Training was not new to the ITU when it was confronted with the introduction of computerization. The union developed its own training school in 1956 as automation became an increasing reality. Management supported these new training programs as a way to minimize the disruption at the workplace and the ITU embraced them as a means to secure newly created jobs. ITU philosophy has been to keep its union strong by its ability to supply employers with the most qualified labor available. During the first phase-in of computerization at the Press in the late 1960's, the newspaper offered typing classes after hours to workers. There was no compensation for the time spent in training. Almost ninety percent of the affected printers volunteered. Those who did not, were characterized as "old-timers" who were planning to retire soon. Two more phase-ins of technology occurred over the next ten years at the Press, and training programs were offered to Local 7 members in one form or another. On-the-job training is the only source of training for Local 7 printers now. Those formerly trained and manufacturing representatives provide the instruction.

Local 6 also actively sought training. At The New York Times, over 200 men applied for training in computer programming when only four positions were available. In selecting trainees at the Times, management and labor developed a system where the function to be automated is examined, those most affected are considered, volunteers are assessed, and lastly, those with seniority are given priority (QWL 77a).

The Pittsburgh Press and The New York Times' slow phase-in of new processes allowed senior linecasters to stay at the machines if they so desired. As of 1977, about half of the Times composing room staff is estimated to have received retraining. Over 29,000 man-hours were devoted to training in 1975, equivalent to more than one week for every employee in the composing room.

But transition did not come easily throughout the industry. In the face of job de-skilling, the printing trade was one of the last craft hold-outs. Historically, through their craft skills, printers were able to gain strong control over the immediate job process. In fact, until recently, the ITU placed more importance over control of jobs than on the issue of hourly wages.

Education was the corner stone of this philosophy, with its four to six year apprenticeship. So when new technologies evolved, the ITU would train and retrain members. It was always assumed that a new technology would increase product demand, whereby displaced workers would be rehired to meet new output levels. This was in fact the case until computerization.

3.4.3 ITU Policies Toward Automation

Attrition Policy

Attrition became the predominant strategy adopted by the ITU and newspaper management to pave the way for computerized typesetting. Attrition served as a survival tactic because computerization did not increase the number of printers required even though newspaper demand increased. Training was no longer sufficient. Thus the ITU was forced to change its traditional method of controlling new technology. An attrition clause generally guaranteed that no employee would be laid off because of technological change, but reserved management's right not to replace any employee who left voluntarily or through death, illness, retirement, or legitimate dismissal. Thus, individuals were protected, jobs were not, and the size of the work force was reduced through attrition. In exchange for this protection, the union would agree that management could introduce technological change to increase productivity.

Starting in the early 1960's newspapers in New York had demanded broader freedom to automate, but in 1965 Local 6 had inserted into the contract a provision barring any automation unless it first approved the terms. This effectively blocked the introduction of any new technology into the city (QWL 77a). This persisted until 1974 when Local 6 reversed its stand and demanded a deal by which management would win the right to automate, in exchange for guarantees of job and union security.

On August 1, 1974, The New York Times, the New York Daily News and Local 6 adopted the Special Agreement on Productivity and Job Security. The agreement set the stage for the attrition policy in these words:

> "The parties... recognize that increasing productivity in the composing room is necessary to the health of the newspaper industry in New York. The parties further recognize that increasing productivity will affect employment opportunities in the composing room.
>
> The intent of this Special Agreement is to permit the publisher to introduce and utilize automation, including any and all computers and technologically improved equipment referred to generally as automation....
>
> The employer shall determine the size of the work force except that no guaranteed employee shall be laid off."

The agreement also provided lump-sum payments to ITU members to act as an incentive to speed the attrition process (ITU New York 73).

Generally for most ITU locals, such as Local 7, the major strategy was to get job guarantees for employed printers, and cut the number of apprentices. When the Pittsburgh Press started to phase in computerized typesetting, Local 7 was motivated to strike. The resulting agreement guaranteed the jobs of union typographers within the composing room.

The attrition clause of Local 7 is worded as such:

> "It is agreed that composing room employees... shall not lose their situation because of installation or expansion of new processes and that this shall remain in effect permanently through succeeding contracts for the named employees. This does not bar negotiating added names in future contracts by mutual agreement."

The contract also contains a clause whereby union workers are given incentives to retire early. The mandatory retirement age for the union is 65. If a worker retires at age 62, he receives a bonus of $10,000; at 63, a bonus of $8,000; and at 64, a bonus of $5,000 (ITU Pittsburgh 77) One aspect of an attrition clause is the right of management to not hire any additional workers. This can surface in the union membership through a decline in the apprentice membership of a local. As the Table below indicates, management exercised their

right quite liberally. Local 7's apprentice figures dropped from 65 to 0 in the years after the attrition clause was agreed upon in 1971. Local 6 experienced a similar drop. Their attrition clause was signed in 1974. Their apprentice membership decreased from 141 to only 12.

Table 3-4: MEMBERSHIP IN ITU LOCAL 6, NEW YORK, NY and LOCAL 7 PITTSBURGH, PA

	Local 6		Local 7	
	Journeyman	Apprentices	Journeyman	Apprentices
1971	10,216	271	813	65
1972	9,909	221	789	66
1973	9,703	178	789	52
1974	9,389	141	779	25
1975	9,091	77	771	8
1976	8,854	42	752	5
1977	8,400	30	746	3
1978	8,155	11	717	1
1979	7,833	12	636	0

SOURCE: ANNUAL REPORTS OF OFFICERS, INTERNATIONAL TYPOGRAPHERS UNION, SUPPLEMENT TO THE TYPOGRAPHICAL JOURNAL, JULY, 1971-1979.

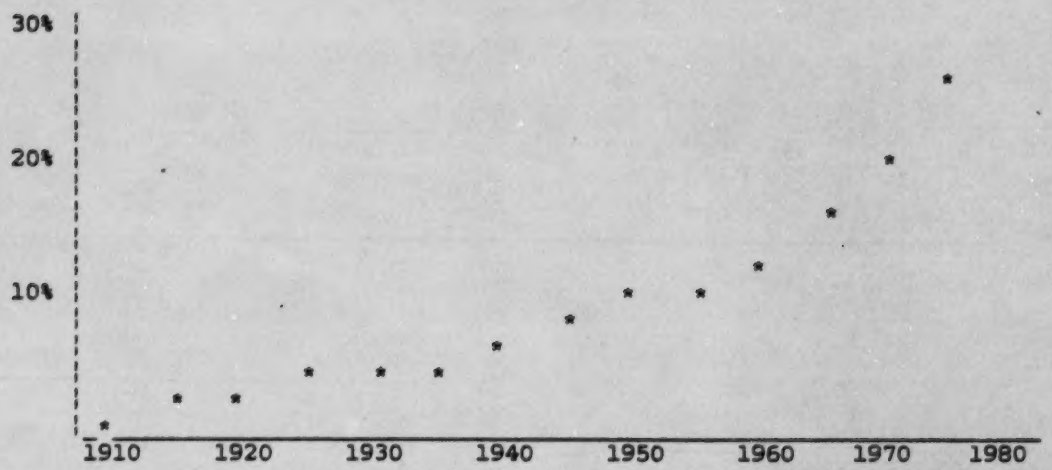
Pension Fund

It has been estimated that it takes 6 workers to support 1 pensioner (Engler 81). When the fund was established this ratio was reasonably maintained due to increasing membership, even though printers were always considered low-age retirees by actuaries. With computerization and the subsequent attrition and buy-out policies there was an increase in pensioners and a decline in membership. By 1975 about 23.5 percent of the ITU membership were pensioned Figure3-3. A lack of financial support was the ultimate result.

The payment system for this fund was a percentage of the ITU members' wages. Generally, the rate was four percent of the weekly wage. The general pension fund received 2.5 percent of the dues and local funds received 1.5 percent. The average payment paid in 1948 was $61.54 increasing to $254 in 1975, thereby reflecting the higher wages of the union members. Despite this increase in wages, there was a general decrease in both the national and locals' funds. (See Figure 3-4)

The reasons for this decline are two fold. One is the increasing administrative cost and benefit payments. In 1948, the average cost per pensioner was $53.89 and by 1975 the average cost rose to $254. The benefits ranged from $10 per month on average in 1944

Figure 3-3: PERCENTAGE OF PENSIONED ITU MEMBERS



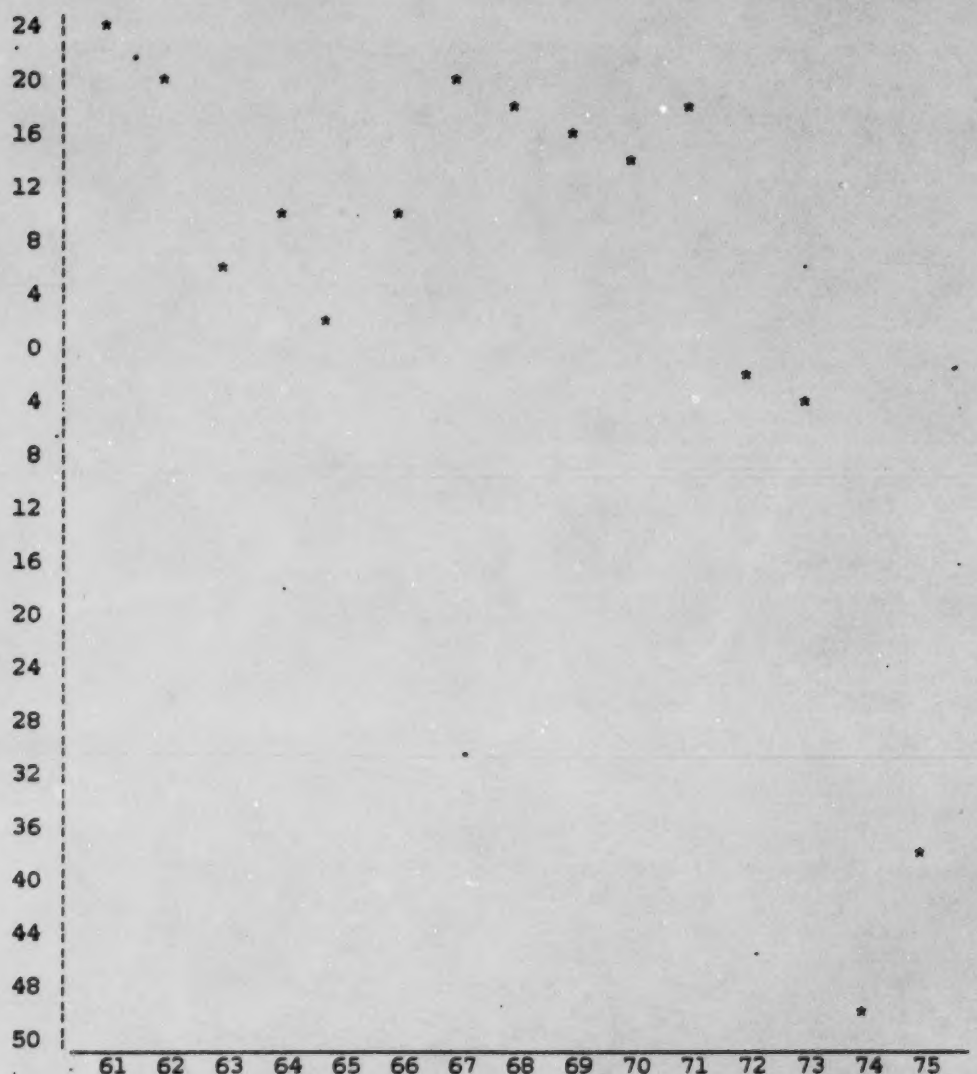
to a maximum of $100 per month in 1968-1974. The benefits jumped most dramatically in 1968 when they went from $22 to $100. This increased cost coupled with increased benefits have added to the demise of the fund. In 1974, the membership voted to have the monthly pension benefit determined by dividing available income equitably among all pensioners (or all members both ill or retired receiving benefits). Otherwise the payment of $100 per pensioner would have resulted in a pension fund balance of $2,500,000, or less than $111 per pensioner in assets. This lack of monies, coupled with the 1974 membership referendum decreasing dues to this fund, caused a sharp decline in the fund balance.

With all of these problems, the pension fund was eliminated in the beginning of 1976. Only those who were receiving benefits at that time, or were retiring in the near future would receive or continue to receive the benefits. As reported by the President of the ITU, in the 1975 annual report to membership

This benefit fund was replaced gradually by an employer paid pension plan, the Negotiated Pension Plan, established in 1967. No longer was it limited to just ITU members, but non-union members as well.

This policy demonstrates ITU's trend away from a specific craft orientation to one of supporting workers of the general field of communications. The amount paid to the fund is contract determined. In 1967 it had assets of $18,444, but by 1972 the assets were valued at $56,036,102 (ITU 75). This is due to the increasing membership and management support of this plan. Often the local's pension or automation fund monies were used for

Figure 3-4: INCREASES/DECREASES IN OLD AGE PENSION FUND



SOURCE: ANNUAL REPORTS OF OFFICERS, INTERNATIONAL TYPOGRAPHERS UNION SUPPLEMENT TO THE TYPOGRAPHICAL JOURNAL, JULY 1971-1979

the initial investment into the plan. This plan is expected to grow and prosper with its policy of union and non-union membership, along with the increasing benefit packages offered by employers.

3.4.4 Summary of the Impacts of Computerized Typesetting

The ITU has changed its focus and tradition. When it was formed in 1852, it represented all printing workers--typesetters, compositors, stereotypers, photoengravers, and pressmen. The introduction of the linotype in 1880 brought specialization to the industry. These crafts split from the ITU to form separate unions by the turn of the century. History has come full circle with recent developments. The decline in the the craft skills has progressed to the point where the various unions are joining forces again. The ITU bolstered its decreasing ranks by 9,700 members in 1970 through a merger with the Amalgamated Lithographers of America. In 1978, the ITU offset decreasing membership further by merging with 11,000 mailers. For the past few years merger negotiations have taken place with the 30,000 member Newspaper Guild, which represents non-craft employees such as reporters, photographers, and clerks.

ITU locals are also attempting to increase their power and size by organizing non-union personnel. For example, in 1980, Local 7 recruited the advertising department of the Pittsburgh Press to their ranks. This merger included everyone from salesmen to artists. Recently, Local 7 has filed a petition with the National Labor Relations Board to request representation of the billing and finance department personnel. Jim Lowen, President of Local 7 described current efforts as a means to revert the local's collective "pleading" process back to one of collective bargaining. (Lowen 81). It is apparent that the ITU is evolving into a communications union.

3.5 CONCLUSIONS FROM THE CASE STUDIES

In their respective industry's, the continuous miner and the computer typesetter had significant impacts on productivity, employment, and job skills. Technological changes in both industries has resulted in higher productivity, a smaller workforce, and the emergence of new job skills. Labor and management policies towards the introduction of new technology differed sharply in coal mining and newspaper printing. The UMWA emphasized the viability of the union more so than the security of the individual worker. No provisions were made for those workers who actually lost their jobs. The ITU's policies had the opposite emphasis. They bargained for job security, and worker protection to the point where it almost threatened the industry, and the union itself.

Alternative policies are being implemented by other unions facing the implementation of

new labor saving technologies. Unions are sometimes participation in the design and deployment of new processes. Some of the craft unions are beginning to reorganizing themselves into industrial unions in order to secure jobs.

The economic condition of the coal and newspaper industries was the predominate factor in adopting new technology. The coal industry was facing a decline in demand before the continuous miner was introduced. In contrast, the newspaper industry was experiencing increasing demand a decade before automation, as income levels and population were rising. Industry growth, however, was not proportional to population growth (Junkerman 78). Substitute goods threatened both industries. Demand for oil and natural gas increased; radio and television encroached on newspaper readership and advertising revenues. Management perceived new technology as a means to achieve a more competitive position with respect to substitutes that were growing in importance in the marketplace.

Economics also shaped labor policy towards the technological change. The UMWA readily recognized the profit to be gained by mechanizing the coal industry in 1948. Their policy of acceptance and cooperation resulted in improved working conditions and higher wages for those workers who remained in the mines, and improved benefits for retired workers. This strategy was not costless, however. Job security was not an explicit goal, and thousands of miners were laid off with no compensation or retraining benefits.

ITU policy provides a sharp contrast. Computerization posed a threat to the typographers craft. Newspapers could hire unskilled labor to fill many ITU jobs. With job security at risk,union locals resisted change. The ultimate acceptance of automation came with a trade-off of attrition and buy-out policies for guaranteed jobs. The radical change in the nature of jobs in the printing industry and the policy of attrition necessitated the establishment of formal training programs by management and the ITU. Subsequently, job security was enhanced through training programs sponsored by labor and management.

Attrition has in turn affected the financing of pension funds. Financing systems have frequently depended upon the number of union members or the number of pension plan members. Since a policy of attrition usually results in declining union membership,there are fewer members left to contribute to the pension fund. The ITU mitigated the impact of attrition upon the pension financing by merging with other unions in the industry and opening pension plan membership to non-union members.

Another policy approach a union might pursue toward financing a pension fund is linking contributions paid by the operators to quantity produced. The pension fund of the UMWA is financed by royalties underwritten by the operators and based on production tonnage.

Such a system of financing is dependent in part on maintaining or increasing levels of productivity. Factors which decrease production, such as industry regulation or strife within the union, have a detrimental effect on such pension financing.

Another strategy which unions could adopt to cope with new technology is participation in the design and implementation of technology. Whether it is realized or not, the designers of technology are inextricably linked to behavior in the workplace (Fadem 76). In the above analysis, the ITU was not involved in such a strategy, and pursued reactive policies--coming *after* technology had been designed and its implementation planned.

Sometimes, technological improvements occur incrementally, and changes in the workplace occur at a marginal rate. This was not the case with computerized typesetting. The new processes were radically different from the ones they replaced. Job characterizations changed completely within a short time span. Former jobs did not resemble new jobs.

Automation and new technologies, such as robotics, frequently result in the elimination of jobs, but also create new jobs-- jobs which require a high level of technical skill and jobs which require few skills. The resulting dichotomy often leads to a decrease in mobility from low skill jobs to higher skill jobs. By organizing the work force such that workers acquire a variety of skills and can rotate jobs--some stability in the workplace can, to some extent, be achieved. Divisions due to differences among workers in prestige and status because of skills acquired would be mitigated. The printer's craft union at the Stockholm Daily News, Sweden, established a system of job rotation controlled by the workers (Junkerman 78). Since technology simplified skills required in a particular job, the worker could master the skills used in several jobs. He would not be limited to a particular specialization. Mastery of a set of skills allows the worker job security-- in that specialized workers can be easily replaced--and the worker has more bargaining power when offering a set of skills to management.

4. THE INTRODUCTION OF ROBOTICS INTO INDUSTRY

4.1 INTRODUCTION

This chapter will focus on industry's experience with robotics in this early stage of their use. It will describe current users of robots and why they decided to use robots. It will look at how the decisions to use robots in these firms were made. It will also assess trends that appear to have developed over the past five years of robot usage, and attempt to suggest how these trends may develop in the near-term future. Finally, the chapter will indicate some of the impacts robots are already having on the organizations that have adopted them.

4.2 METHODOLOGY

In order to gauge industry's experience with robotics, a field survey and interviews were conducted. (See page 141 for detailed information on the survey and interviews.)

During the Winter and Spring of 1981, project members conducted a survey of the 124 firms belonging to the Robot Institute of America (RIA). RIA classifies their members into five categories:

1. manufacturers
2. distributors
3. accessories manufacturers
4. researchers
5. corporate users

There are 78 members in the corporate user class, which includes most current users in the U.S., as well as a number of prospective users. The survey consisted of thirty-three questions, seven of which characterized the responding firm by size, type of production, and robot use. One question was designed to assess why firms are using or are planning to use robotic technology. The remaining questions addressed the impacts of robotization on the work force, the production process, and on the different levels of management in the organization.

Thirty-eight firms had responded to the survey by May 1, 1981.[10] Of the respondents, 19 are currently using robots, while the remaining 19 are now considering adoption. The

[10] Additional responses have been received but have not yet been tabulated.

responding firms had a total of 579 robots in use. Some firms which use robots in several plants filled out the survey for a particular establishment, others answered on a corporate-wide basis.

Thirty-one interviews were also conducted. Two were in-person, and twenty-nine were over the telephone. Some of the interviews were conducted primarily to follow up on questionnaires that were received. Others collected information from those who were not part of the RIA sample. The interviews were particularly useful in gathering in-depth information on how firms made the decision to adopt robots.

The pooled sample of questionnaire respondents and those interviewed had approximately 1260 robots currently in use, nearly one-third of the U.S. robot population as of January, 1981. More detailed information profiling our respondents is given in the section on the rate of introduction. Those interviewed were promised anonymity, so corporations are referred to in this report by code names, e.g. "B corporation interview."

4.3 REASONS FOR USING ROBOTS

Survey respondents were asked to rank, in order of importance, the factors influencing them in their decision to install robots.

Table 4-1: MOTIVATIONS FOR USING ROBOTS

RANK	USERS	PROSPECTIVE USERS
1	Reduced Labor Cost	Reduced Labor Cost
2	Elimination of Dangerous Jobs	Improved Product Quality
3	Increased Output Rate	Elimination of Dangerous Jobs
4	Improved Product Quality	Increased Output Rate
5	Increased Product Flexibility	Increased Product Flexibility
6	Reduced Materials Waste	Reduced Materials Waste
7	Compliance With OSHA Regs.	Compliance With OSHA Regs.
8	Reduced Labor Turnover	Reduced Labor Turnover
9	Reduced Capital Cost	Reduced Capital Cost

Other factors mentioned:

- To give an image of innovativeness.
- To keep up with the Japanese.

SOURCE: CMU ROBOTICS SURVEY: APRIL, 1981

Nine possible motivations were listed. A rank of one indicated the factor that was the

most important in their decision to introduce robots. An average ranking for each motivation was calculated by totalling all rankings given that factor, and dividing that sum by the total number of rankings received. Thus, the lower the mean score, the more important the motivation. Based on the mean score for each ranking, the motivations have been ranked ordered below. The results for users and prospective users are shown separately in Table 4-1.

There was strong agreement between users and prospective users on the five most important motivations, but the ordering differed between the two groups. Both groups agreed that reducing direct labor cost was the most important reason, but users gave more importance to eliminating dangerous and tedious job while prospective users were more concerned with product quality.

4.3.1 Labor Cost

In a recent book on robotics, Joseph Engelberger, president of Unimation Incorporated, proposes that

> ...the driving force behind adoption of robots in manufacturing plants is cost saving. While quality improvement and increased throughput produce some of the savings, labor displacement is the central benefit. Robots contribute to productivity primarily by displacing human workers.[11]

Our evidence strongly suggest that many users and prospective users share this view. Survey respondents *overwhelmingly* ranked efforts to reduce labor costs as their main motivation for installing robots. Current trade journal articles also give this as the primary motivation. Hourly labor wage estimates, including all benefits and support cost, range as high as $18.10 (USNews 81a) for some auto industry employees. Several respondents indicated that the "true" cost of an hourly employee to them exceeded $30,000 a year. Assuming 2000 working hours to a year, this comes to over $15.00 per hour. Figure 4-1, an estimate of robot-human cost differentials, compiled by Engelberger, clearly shows how the robot manufacturers are emphasizing the potential for cost saving . There are some questions as to whether Engelberger's estimate of the "all included" cost of a robot is as comprenensive as the "all included" cost for labor. One respondent , from a firm with extensive robot experience, pointed out that many of the "intangible" indirect costs associated with bringing a robot on line and maintaining it are often overlooked. Even allowing for some understatements of "true" robot costs, there is widespread agreement among robot users that these machines do effectively cut costs, in addition to sometimes providing other benefits.

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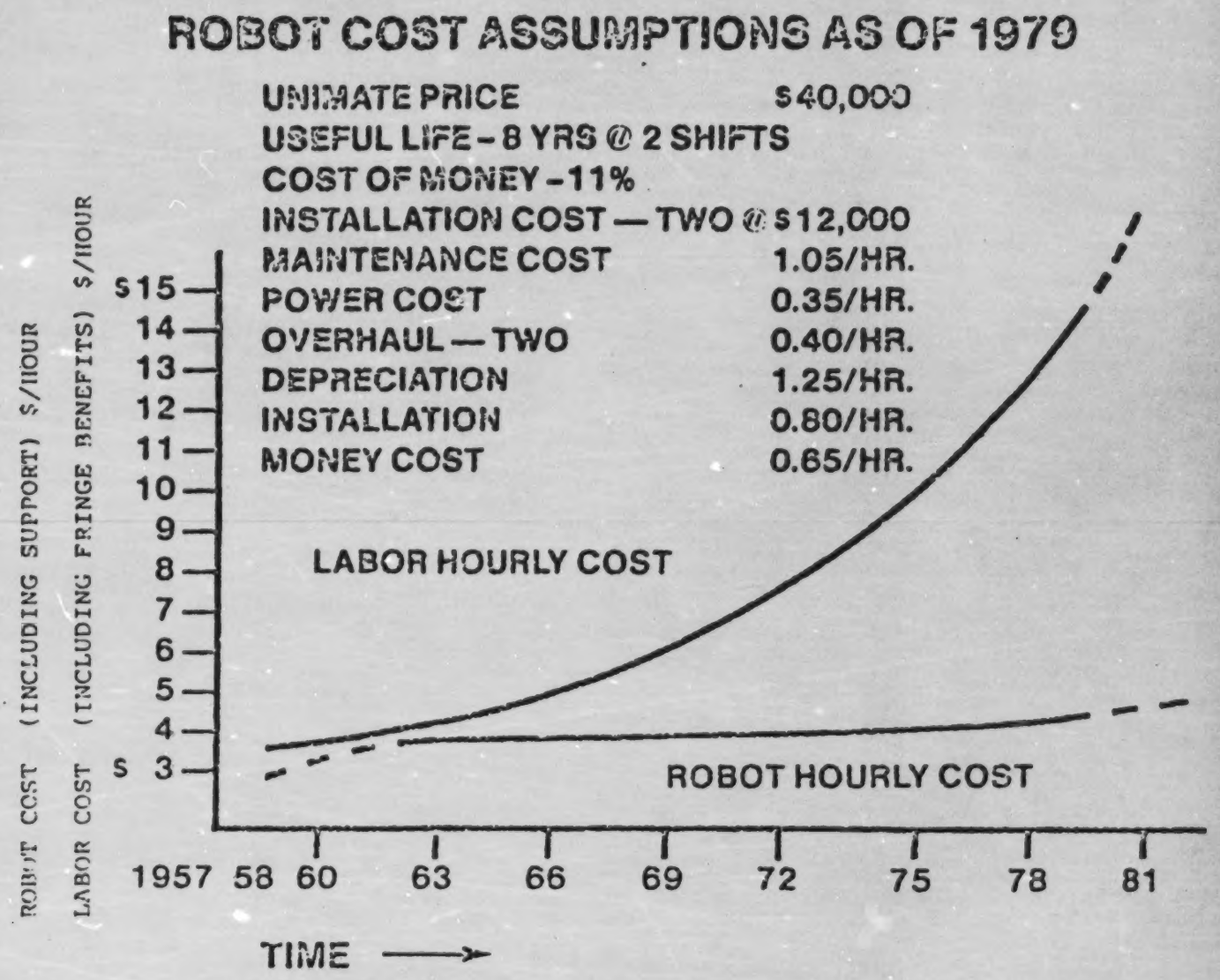
[11] (Engelberger 80b), page 115

Figure 4-1: A COMPARISON OF ROBOT AND HUMAN COSTS



HISTORY OF LABOR COST AND HISTORY OF UNIMATE ROBOT COST IN THE AUTOMOTIVE INDUSTRY

Source: (Engelberger 80a), page 5.

Many of the respondents who were interviewed suggested that the heavy emphasis on direct labor savings was imposed by the methods of financial analysis used to evaluate robot applications. Almost all the firms interviewed based their decisions to use robots on a financial analysis of costs and benefits. One user pointed out that the Return on Investment (ROI) calculation will not be favorable unless there is a dramatic decrease in direct labor costs. He added that arguments about improving product quality or increasing production flexibility were nebulous, and did not carry as much weight with the financial people as direct labor savings. Given that financial analysis requires short term payback, or high ROI, it is understandable that there is such a heavy emphasis on direct labor saving. Aside from increased output, it is the only variable that is quantifiable in a straightforward fashion.

4.3.2 Elimination of Tedious and Dangerous Jobs

Respondents to our survey considered the elimination of tedious and dangerous jobs second in importance . It should be noted that for some respondents, this motivation was related to direct labor savings. One respondent (See Q corporation) said that there is no difficulty in incorporating this motive into an ROI framework, i.e. the elimination of a dangerous or unpleasant job can also reduce labor costs for a firm. On the other hand, an executive from L corporation commented that the financial people at his firm do not accept this argument, because it is difficult to quantify.

A respondent from a large multi-plant firm speculated that this rationale is an important factor in early adoption to help gain the acceptance of robots by labor, but would be less important later. More broadly, there would seem to be an obvious public relations value to this justification for the use of robots.

4.3.3 Output Rate

The ability of robots to increase output is a benefit often stressed in the current literature, though planners are frequently unable to determine beforehand the extent to which they will gain this benefit. Output increases of over 100% have frequently been mentioned in the trade literature. For example, General Dynamics claims a four fold output increase in the fabrication of wing panels (AM 80a). A respondent from Corporation F said, "Sometimes the productivity increase is so damned high we can justify the robot without removing direct labor."

Over two thirds of our users claimed that the average length of the work shift per day increased when robots where used, which in itself would lead to an increase in output. Two users said that the average number of shifts actually decreased as a result of using robots, and all others said there was no change in the number of shifts.

It should be stressed, however , that the use of robots does not always lead to increased output. An executive from Corporation C, for example noted that when robots were retrofitted into his plant, other factors had limited the rate of output.

4.3.4 Product Quality

Product quality was the second most important motivating factor for prospective users of robots, and fourth for current users. This may be because the search for improved product quality has intensified in recent years because of the increasing quality of imported foreign products. In the auto industry, this search for improved product quality has been a major motivating factor in the decision to invest in robotics. Chrysler Corporation, for example, claims that an effort to boost product quality was one of its major reasons for installing robotic welders in two of its "K-car" plants. Ninety-eight percent of the welding done at Chrysler's Newark, Delaware plant is done by robots. It is hoped that more consistent high quality welds will cut warranty and repair costs as well as promote the sales of the new cars (AM 80b). Similar hopes of improved product quality prompted General Motors corporation to install two robotic welding lines in its Detroit Fleetwood body plant at a cost of 8.5 million dollars. The robotic lines replaced only six welders, resulting in a labor cost saving estimated at only $120,000 per year. Leslie Richards, a G.M. Assembly Division official views the robots as an investment in quality that has a ripple effect in cutting costs (WSJounal ??).

Among respondents to our survey, all of those who ranked product quality as one of their three most important motivating factors reported that robots had indeed improved quality. Interestingly, more than half of the firms that gave quality less importance as a motivating factor also reported an improvement in quality. Almost two thirds of users said that the percentage of parts rejected in the robotic operation had decreased. The remainder said there was no change in rejection rates. Four respondents said that quality control specifications had been tightened where the robot was used. Only one respondent reported a change in the number of quality control employees needed, and this was an increase.

F corporation and a few others reported that efforts to place a dollar value on product quality improvements, but most noted that this is a recent development.

4.3.5 Production Flexibility

Robots are considered a flexible technology because their reprogrammability allows them to be quickly adapted to changes in the production process. Robot flexibility has two aspects. First, a robot may be programmed to perform the same task on a variety of

different work pieces. This type of application is commonly seen in several areas such as robotic spot welding. A second type of flexibility involves shifting the robot to an entirely new task. Despite the frequent mention of this factor in the trade literature, it was not an important motivation to our respondents. Some noted the difficulty in assigning a dollar figure to flexibility.

Evidence from interviews suggests that once installed, robots have rarely been transferred to new applications. In I Corp., a robot no longer needed for its assigned task, taken off line, sat idle because no one in the division wanted to invest the time to adopt it to a new application. An senior engineer from O corporation complained that production engineers are so used to thinking in terms of hard automation that is is difficult to get them to think in terms of using programmable automation.

There was a large spread in the priority given to flexibility by respondents, and some manufacturers, such as B corporation, did view increased flexibility as an important impact. This view seems most prevalent in industries with frequent major model changes such as the auto industry.

Two respondents said that using robots had enabled them to manufacture more complex designs (another type of production flexibility), and eight claimed that robots had reduced set up times in the operations where they were used.

4.3.6 Other Factors

The possible ability of robots to help ease compliance with OSHA regulations was felt by most respondents to be relatively unimportant in their decision to implement robotics. Two respondents did say that robots had reduced the number of production-related accidents where they were used.

Two users said that using robots increased efficiency in raw materials usage. One application which has resulted in considerable materials savings is robotic spray painting. At General Electric's Hotpoint dishwasher factory in Milwaukee, a single robot saved $19,000 worth of paint in one year while achieving improved coating uniformity (Business Week 80). While some of this material saving occurred because of the increased spraying accuracy of the robot, a large saving resulted because the vacuum units installed to protect workers from paint fumes no longer had to be operated.

4.4 THE DECISION TO IMPLEMENT ROBOTS

The decision to use robots at a firm begins with an initial proposal to install, and is followed by a financial analysis , and an engineering analysis of the application.

4.4.1 The Proposal

For the few firms that are experienced users, the idea to install additional robots has usually originated from plant personnel. The experience at C corporation is fairly typical. With most inexperienced robot users however, the idea to install has usually originated from corporate headquarters. At L corporation for example, top management told plant managers to "do something about robots," and even set robot quotas.

An exception to this is J corporation, an inexperienced user, where the idea and motivation for using robots came from the operational level within the plant. The push for robots came from the plant because because headquarters personnel did not have the technical background in process improvement.

At multi-plant firms with both experienced and inexperienced plants, the patterns are combined. Q corporation, for example, started to promote the idea of using industrial robots in its various plants several years ago. They classify their plants into three categories. First, there are plants that have robot experience. These plants are mostly self-sufficient in that they now decide how, when, and where to install robots. According to the company spokesman, "They have picked up the ball and run with it." The second category is plants which are not now using robots. These seek assistance from the company's technical center in developing applications. Finally, there are those plants that do not use robots and are not currently interested in doing so.

4.4.2 Evaluation of Robot Expenditures

When evaluating capital expenditures, the management of any profit-oriented firm is concerned with financial performance. Expenditures for robotic equipment are no exception. Robots may offer a wide variety of benefits, but if they cannot pass the test of a critical financial appraisal, it is unlikely that implementation will occur. Current industry practices for evaluating the desirability of a particular robotic expenditure include a calculation of the payback period and a calculation of the rate of return on investment.

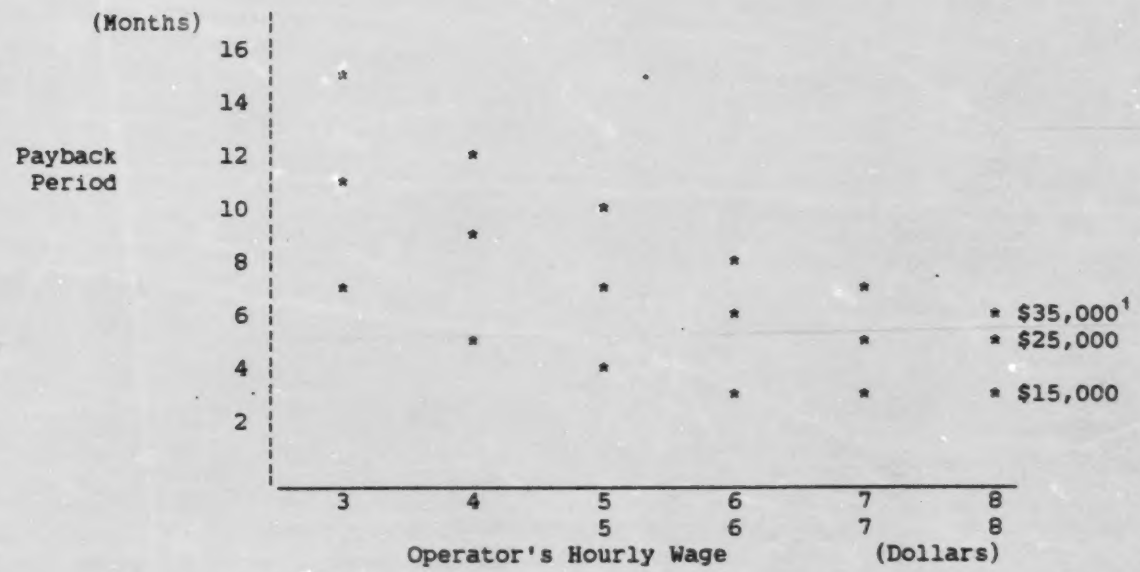
The payback period calculation estimates how much the project will cost and how soon the investment will be recovered. The following formula for the simple payback period is taken form (Engelberger 80b), page 105:

$$P = \frac{I}{L-E}$$

Where P = the payback period in years
I = total capital investment required in robot and accessories
L = annual labor costs replaced by the robot
E = annual maintenance costs for the robot

The payback period is the ratio of initial investment costs to average annual savings in unit manufacturing costs over the lifetime of the robot. Generally, financial advisors look most favorably upon those projects which pay for themselves within three years. In plastics molding parts removal applications, it has been estimated that the payback through reduced labor alone ranges from three to sixteen months.(See Figure 4-2.)

Figure 4-2: PAYBACK ON PARTS-REMOVAL ROBOTS THROUGH LABOR SAVINGS



1) Installed Cost of System

SOURCE: MODERN PLASTICS JOURNAL, JUNE 1978, P.50.

The graph is based on a 25% tax/benefit package for a single machine operator on a three shift/day-five day/week schedule. The data shows that investments in robotic equipment can have very short payback periods after which they produce profits for the firm.

Payback analysis is most useful for a short time frame. Since the investment in robots will generally produce useful work over a period of many years, another method of analysis is required which will evaluate the long term attractiveness. The calculation of return on investment is one such method.

A simple formula for calculating rate of return on investment , from (Engelberger 80b), page 108, is given below:

$$ROI = \frac{(S \times 100)}{I}$$

where:
ROI = return on investment (%)
S = annual savings resulting from the robot
I = investment in robot and accessories

$$S = L - C$$

where:
C = annual robot costs
l = annual labor costs replaced by the robot

$$C = \frac{I}{N + E}$$

where:
I = investment in robot and accessories
E = annual maintenance costs of the robot
N = useful life of the robot

Judging from our interviews, the great majority of firms project the payback period and return on investment when evaluating the decision to install robots.[12]

Both payback and return on investment analysis tend to focus on direct labor cost because these are easily quantifiable.

[12]The formulas given above are not necessarily used. There are a number of variants of these types of calculations, some adjusting figures for inflation, or discounting future cost.

4.4.3 Quantifiability of Robot Benefits

Robots can yield many benefits in addition to direct labor savings,e.g. product quality improvements, increased throughput, better worker satisfaction, reduced indirect material requirements, increased reliability in production, and increased production flexibility. Our interviews indicate however, that most firms do not attempt to quantify "indirect" benefits in their financial analysis of the robot. Apparently, these types of cost are too difficult to measure. Prospective users have difficulty calculating the value of indirect benefits before they have a historical record of cost savings. These records take several years to accumulate, even if accountants are systematically monitoring these issues. Direct labor savings, on the other hand, is relatively easy to quantify by using the direct wage rate and standard overhead factors.

The question was raised as to whether experienced users *learn* how to quantify "indirect benefits" as they accumulate experience with using robots. An executive at one firm speculated that inexperienced users only take direct labor cost into account because they do not know what other categories of cost will be affected. He said that after two years of robot use, his firm had learned how to quantify other indirect benefits such as improved product quality and reductions in indirect material requirements.

Other experienced users did not report this kind of "learning". An aerospace components manufacturer indicated that they continued to justify their applications on labor savings. A large transportation equipment manufacturer said that after twenty years of robot use, their main motivation was still labor saving. A representative from another firm in the same industry commented that in six years of using robots, they have not changed their financial analysis (or motivations) drastically. Reducing direct labor cost was still the prime reason for using robots. Thus, there are differing opinions among experienced users as to whether the analysts *learn* how to quantify indirect benefits as they gain additional robot experience.

The executive from B Corporation speculated that transportation equipment manufacturers would be spending billions of dollers in the next few years on new tooling (including robots) for reasons other than direct cost savings. He said the main motives were to improve their competitive position vis a vis the Japanese,and other American manufacturers.

The example of the $8.5 million welding line installed to replace 6 welders mentioned on page 52 may be a case in point. At other firms, managers reported investing heavily in robots because they wanted to "leapfrog" the competition. They thought they could do this by becoming adept with an emerging technology which *potentially* could give them superior manufacturing capabilities.

Thus, broader strategic concerns such as long term competitivness apparently are considered, yet they are seldom mentioned as the most important motivations. Only one firm, B Corp., said outright that they had invested heavily into robotics to improve the quality and the competitive standing of their product. They were also the only firm to give strong emphasis to other intangibles such as improved production flexibility. Interesting enough, this spokesman was the only person among all those interviewed to say that applications were not evaluated primarily on ROI or payback period.

4.5 ORGANIZATIONAL ADAPTATIONS

With the introduction of robotics, organizations have had to make several adaptations--some to facilitate the introduction of the new technology, others to allow its effective use. Steps are generally necessary to gain the acceptance of robots by the workers. Operatives must be retrained and provisions for their safety must be made. Changes in organizational structure and managerial duties are often found to be desirable. Sometimes the production process is substantially modified to take advantage of the new capabilities offered by robots.

4.5.1 Informing the Workers

The first stage of introduction involves informing the workers. Sullivan (Welding Journal 80) expresses the workers' concern with the "people considerations involved in the introduction of robots. He states, "It is the responsibility of management at all levels to carefully prepare employees for the transition." Programs which accomplish this can help to eliminate psychological problems with the workers. One auto manufacturer reports that when they have notified the workers that robots were going to be installed, the workers have been very cooperative. Fears of being replaced or laid off are said to be calmed when the workers realize the advantages a robot can afford. Of the firms surveyed, the notification period averaged 4.3 months. The interviewed firms indicated a general consensus that this is a very important step in supporting management-labor relations. One respondent said that it helps prevent a feeling of surprise and distrust among the workers. Three of our respondents using robots, however, indicated that no notice was given to workers before robots were introduced.

4.5.2 Training the Workers

Survey results indicate that over 70% of the workers whose jobs were displaced were retrained to either work with the robot which took over their duties or to perform other jobs within the plant. Ninety percent of the newly created positions were filled by retraining the present workers. Nearly seventy percent of the surveyed firms had help from

the robot suppliers with their retraining efforts. Typically, experienced maintenance people required a week of formal training to adapt their skills to robots.[13]. One firm indicated that six to eight months of on the job training followed the schooling provided by the robot vendors. Regarding the skills involved, 60% of the firms surveyed indicated that the operative jobs have had a increase in skill level while 86% indicated that the maintenance jobs have had an increase in skill level. Our respondents reported few problems in transferring maintenance workers and machine operatives to robots.

As for the concern with being replaced by robots, it was emphasized that no one has been laid off because of a robot in major corporations. Many trade journal references relate attempts by management to retain displaced workers by transferring them to other jobs within the plant. Some interviews indicated that the number of jobs actually increased due to the necessary installation, maintenance, and servicing duties involved with the robots. This early experience, however, may not be representative of the future. As Chapter 1 noted, there was little displacement of workers in the early stages of adoption of continuous mining machines, but then the diffusion of this equipment abruptly increased and the work force was sharply reduced. Furthermore, while there have been no reported lay-offs due directly to the introduction of robots, a die casting company reports that robots increased the output of the firms machinery so greatly that the operation of some of the firm's non-robotic equipment no longer proved profitable during a business slowdown. Some machine operators were laid-off as a result (AM 80c). Workers may be laid off because they are "bumped" out of a position by a more senior worker whose job was automated with a robot. Once the chain of events grows to several links, firms can still claim in all honesty that no worker has lost their "because of a robot." In addition, several respondents indicated that they are allowing attrition to reduce the size of their work force.

4.5.3 Worker Safety

A further consideration with respect to labor is that of safety. The new working environment may include a robot which does what it is programmed to do regardless of what (or who) gets in its way. Seventy-one percent of the firms surveyed indicated that they had had to adopt some new safety measures to protect the workers. Several robot users fenced off the robots off from the workers to avoid any accidents. On the other hand, robots can also reduce the number of safety related problems within a firm. According to survey results, the second most important motivation for implementation of

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[13] A description of the maintenance and operation training programs offered by several of the robot manufacturers is given in page 205

robots is to reduce the number of tedious and/or dangerous jobs which could mean a reduction in the number of accidents. For example, a respondent from company F stated that robots have reduced the number of accidents within his company because they now handle the glass products which had previously cut many workers.

4.5.4 Organizational Structure and Managerial Duties

Nearly one-third of our respondents reported that new organizational units had been created as a result of the introduction of robots or CAM[14]. None, however, had eliminated or consolidated existing departments. More than half the robot users had implemented automated inventory control systems. Several large firms, e.g. F and G corporations, have established robot planning groups at the corporate level. These groups are involved in promoting robotic applications within the company, evaluating new technological advancements for their applicability within the firm, planning for future applications, and helping individual plants to gain the maximum possible number of benefits from robots. Still other firms, e.g. H Corp.(HA Division), have set up robot workshops. Five respondents had created new robot-specific management positions, but the other respondents had not. Three of the five hired managers from outside the firm to fill some of these newly created positions.

4.6 TRENDS IN THE USE OF ROBOTS

In addition to collecting information on the current state of industry's experience with robotics, our questionnaires and interviews were also designed to elicit information on trends that may be developing. We were particularly interested in what changes had occurred with respect to the industries in which robots are used, the extent to which the increase in the robot population was due to increased usage by firms that were already using them as opposed to diffusion to new firms, changes in the production batch size of firms using robots, and changes in the size of the establishments using robots. Accordingly, we asked respondents for information about their robot usage in 1976, in January 1981 and their projected use in the near future.

4.6.1 Industries Using Robots

As can be seen from Figure 4-3, the major U.S. auto makers represented four out of the twelve firms among our respondents who had robots before 1976. Fifteen firms in other industries acquired robots after 1976.

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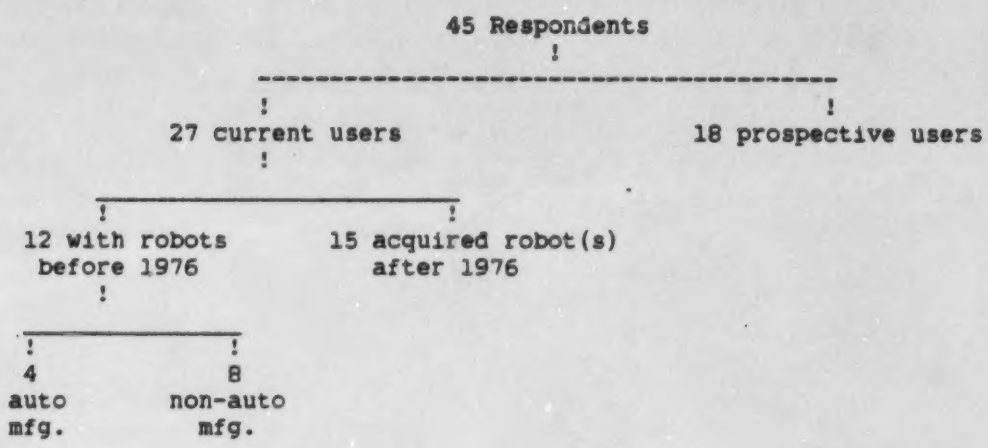
[14] Computer Aided Manufacturing

Figure 4-3: RESPONDENTS TO SURVEY AND INTERVIEWS



SOURCE: CMU ROBOTICS SURVEY, APRIL, 1981

Characteristics Of Robot Users In The Sample

As can be seen from table 4-4, all the pre-1976 users of robots were large firms with more than 1,000 production workers in the establishment where robots were used. Seven of these establishments, including the four auto makers, were engaged in mass production (more than 10,000 units per production run). Four of the establishments were classified as small batch (100 to 1,000 units per production run) or large batch (1,000 to 10,000 units per production run) production. One firm, in the aerospace industry, used robots in custom production.

After 1976 the use of robots spread to smaller size establishments, with one-third of the new users having fewer than 1,000 production workers. More mass producers began using robots, but even more of the new entrants were engaged in custom production. Most of these custom producers were aerospace firms.

Of the prospective users among our respondents, half have fewer than 1,000 production workers. Establishments engaged in mass production account for only about one-fifth of these establishments.

Thus our data suggests an expansion in the applicability of robots, from large firms to smaller ones and from mass production to custom and batch production. Several of the early large users were auto makers engaged in mass production. Later entrants among the large firms included aerospace firms engaged in custom production. Smaller firms in our

sample, primarily capital goods manufacturers, also have started using robots or plan to do so.

4.6.2 The Diffusion Of Industrial Robots

Figure 4-5 compares diffusion between firms and diffusion within firms that had robots before 1976 with those that acquired robots after January 1976. It further breaks down our sample between automakers and other firms. There was a five fold increase in robot use by the auto makers. There was also more than a five fold increase among users outside the auto industry, with most of the increase concentrated in two firms. Experienced users accounted for over 90 percent of the robots in the sample added between 1976 and 1981, and almost 90 percent of the increase within all experienced users was accounted for by five firms. Even within the newer (post 1976) users, over half of the robots were owned by one firm.

An important question is the degree to which robot use will remain concentrated within a relatively small number of firms. It is clear that the use of robots is spreading rapidly within a small number of firms where robots are well suited to production process. On the other hand, a growing number of firms are also purchasing one or a few robots to evaluate them in a new environment.

Robot use among some of the experienced users will continue to increase at an accelerating rate. General Motors, for example, has announced plans to increase the number of robots in their plants by a factor of nearly fifty by 1990. Some 98 percent of the robots they plan to use by the end of the decade have not yet been installed ! Equally significant is their estimate of the anticipated shift in robot applications. For example, the percentage of robots used for assembly jobs is expected to increase from three percent to thirty-six percent, while the percentage of robots used for welding jobs will drop from forty-three percent to twenty percent.

The projected usage of robotics within General Motors represents exponential growth. Other studies also predict exponential growth. In a recent Business Week article (Business Week 80), Bache Halsey stuart Shields, Inc. projects a constant growth rate of between 30 and 60 percent for worldwide sales of robots. Engelberger believes that a 35 percent constant growth rate is likely. Based on the assumption of 3500 robots in the U.S. in January 1980, the number of robots that would be in use in 1985 and 1990 assuming various constant growth rates is shown in Table 4-3.

Figure 4-4: PROFILE OF SURVEY RESPONDENTS

PRE-1976 USERS

USERS (NUMBER OF ROBOTS)		Batch Size			
		Custom	Intermediate	Mass	Total
Firm Size (employees)	1-99				
	100-499				
	500-1000				
	> 1000	1(10)	4(28)	7(111)	12(149)
	TOTAL	1(10)	4(28)	7(111)	12(149)

POST 1976 USERS

USERS (NUMBER OF ROBOTS)		Batch Size			
		Custom	Intermediate	Mass	Total
Firm Size (employees)	1-99	1(1)			1(1)
	100-499			2(5)	2(5)
	500-1000		1(3)	1(1)	2(4)
	> 1000	6(62)	1(2)	3(9)	10(73)
	TOTAL	7(63)	2(5)	6(15)	15(83)

SOURCE: CMU ROBOTICS SURVEY, APRIL, 1981

PROFILE OF PROSPECTIVE USERS

USERS		Batch Size: Custom	Intermediate	Mass	Total
Firm Size (employees)	1-99	1	1		2
	100-499	2	3		5
	500-1000	1	2		2
	> 1000	2	2	4	8
	Total	6	8	4	18

SOURCE: CMU ROBOT SURVEY, APRIL, 1981

NOTE: A FIRM PRODUCING OUTPUT IN MORE THAN ONE BATCH SIZE WAS CLASSIFIED ACCORDING TO ITS PREDOMINANT BATCH SIZE.

Figure 4-5: BREAKDOWN OF ROBOT POPULATION BY EXPERIENCED AND NEW USERS

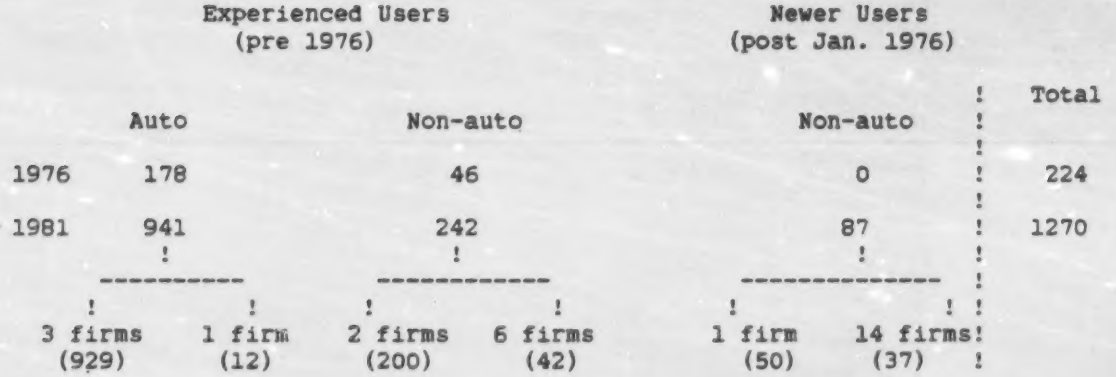


Table 4-2: ROBOT USAGE AT GENERAL MOTORS

	January 1981 (ACTUAL)		1990 (PROJECTED)	
	number	% of total	number	%of total
Assembly	9	3%	5000	36%
Machine Loading	55	18%	4000	28%
Part transfer	16	5%	800	6%
Welding	131	44%	2700	19%
Painting	40	13%	1500	11%
Misc.	51	17%		
Total	302	100%	14000	100%

SOURCE: GM MANUFACTURING DEVELOPMENT CENTER, WARREN, MICHIGAN.

Table 4-3: ROBOT POPULATION AT SELECTED GROWTH RATES

Robot Population in Year	Constant percentage growth rate per annum		
	20%	35%	50%
1985	8710	15,695	26,579
1990	21,672	70,376	201,832

BASED ON 3500 ROBOTS IN USE IN JANUARY 1980.

Table 4-4: CUMULATIVE NUMBER OF MANUFACTURING ESTABLISHMENTS BY SIZE

	Number of Establishments with		
	100 or more employees	1000 or more employees	Total Establishments
METALWORKING (SIC 34-37)	11,477	1,057	98,165
ALL MANUFACTURING	38,466	2,337	325,443

SOURCE: BUREAU OF THE CENSUS, DEPT. OF COMMERCE, 1981 COUNTRY BUSINESS PATTERNS, 1978 UNITED STATES SUMMARY.

Constant growth rates ranging form 20 to 50 percent per annum seem large,but one can demonstrate the plausibility of such estimates. Indeed, these rates may even be conservative. A constant growth rate of 50% would result in over 200,000 robots in use by 1990. Given that there are 11,477 establishments within metalworking alone with 100 or more employees, an average of 18 robots per establishment could absorb all 200,000 robots. As our survey indicates however, robot usage is expanding outside the metalworking industry. Given that there are 38,466 establishments with 100 or more employees in all manufacturing, an average of six robots per establishment would be required to absorb all 200,000 of them.

4.6.3 Retrofitting vs New Plant Installations

Three fourths of all users said that all of their robots had been retrofitted into existing plants, though this includes a few instances where robots were put on a new production line in an old plant. Only two users said they had put robots only in new plants, and three said they had installed them in both existing and new plants.

We can only speculate as to why most users are retrofitting robots, despite acknowledgements that their effectiveness is often limited by space constraints and by limitations in other types of equipment, or processes. Our informal observations suggest that users are still trying to learn how and where to use robots. Even the five firms which accounted for most of the new robots in our sample typically retrofit just a few of them at a time into a given plant. This may well be a more reasonable strategy than rushing to build new robotized plants when one considers how few people know how to design and lay out a plant that is optimized for robots, as opposed to humans.

Twenty respondents, including both current and prospective users, said they intend to put robots into existing plants within the next five years. Fourteen respondents said they plan to install them in both new and existing plants before 1986.

5. CHARACTERIZATION OF ROBOT CAPABILITIES AND MANUFACTURING JOBS

5.1 INTRODUCTION

To evaluate the potential for robotization, the following questions are addressed:

- What is a robot?
- What are the capabilities of robots?
- What tasks can robots perform?

After establishing a basis for the capabilities of robotics, a comparison is made of job skill requirements and robot capabilities. Then we assess the potential robotics applications within each class. This helps us to determine where robotics can compete with the human labor force most effectively.

5.2 OVERVIEW OF INDUSTRIAL ROBOTS

5.2.1 Definition of a Robot

In 1979, the Robot Institute of America adopted a definition for an industrial robot.

> "A robot is a reprogrammable multi functional manipulator designed to move material, parts, tools, or specialized devices, through variable programmed motions for the performance of a variety of tasks."

Robots are reprogrammable, that is to say their actions can be modified by providing a new set of instructions, without modifying the hardware. Because it is reprogrammable, the same general purpose machine can be used to perform the same basic task on a number of different (though probably similar) workpieces. Or, it can perform a variety of different tasks on a single workpiece.

5.2.2 Capabilities of a Robot

Presently, industrial robots have major limitations related to the speed of the arm, the amount of force, or payload it can deliver, the precision of the motions, the ease of programmability and the complexity of the sequences of actions it can be instructed to do. The key attributes of any robot include learning, decision making, sensing, manipulation, mobility, and reliability.

It is helpful to classify robots into two distinct groups. The first type is labeled as "level

one." This generation of robots lack sensory feedback capabilities. Commercially available, "off the shelf" models available today are what is meant by Level I machines.

The fundamental limitation on present day robot capabilities relates to the need for pre-specification of each task in complete detail. The capabilities required to surmount problems of dealing with non-standard workpiece orientation and variable workpiece attributes can be summarized under the two added headings:

- sensing ability,
- learning ability.

In order to surmount many of the limitations imposed upon present day robots , a second generation of robots referred to as "Level II" is under development. The first generation of level II robots are still in the laboratory and test stage. Still, many of these future sensory capabilities can be roughly defined. The attributes of a sensing robot can be organized in the same manner as those of a non-sensing robot. Table 5-1 displays the range of capabilities of both Level I and Level II robots.

Rudimentary vision and tactile sensing are two of the principal features of a level II robot. Visual ability is important because it permits the device to distinguish exactly where things are, and how they are oriented. Tactile sensing plays the same role for a robot as for a human: it provides confirmation that a tool is, in fact, being gripped correctly, or that a bolt fits into a hole as it should.

One of the major research efforts for Level II robots is coupling real time sensing devices with feedback control systems. Providing a robot with this capability will enable it to sense its own motion and position in relation to the working environment. Advancement in the specific areas just mentioned, along with the other capabilities cited, are rapidly changing and expanding the variety of tasks which robots can perform.

5.3 TASKS ROBOTS CAN PERFORM

A classification of task common to many industries that robots are generally capable of doing is given in Table 5-2.

A list of applications where robots are used within the auto industry is given in Table 5-3 Robots are used in many of these same applications in other industries as well.

There are several tasks which would seem to be an ideal application for a robot, but are unexpectedly complex for a level I device. As an example, during the process of deburring,

Table 5-1: CAPABILITIES OF PRESENT AND FUTURE ROBOTS

	Commercially Available Capabilities(1980) (Level One)	Capabilities Sought for the Future[15] (Level Two)
Learning	fast programming via teach and playback modes	
Decision Making	random program selection by external stimuli	rudimentary vision
	computer interfacing	tactile sensing
Sensing		computer interpretation visual, tactile data
	six infinitely controllable articulations between base and gripper	voice communication
		general purpose hands
Manipulation	position accuracy repeatable to 0.3 mm	multiple hand to hand coordination
	handles up to 150 kilos palletizing/depalletizing	
Mobility	synchronization with moving workpieces	
Reliability	400 hours for mean time between failures	

Source: (Engelberger 80b), page 117-118.

[15] The future robot capabilities described here go somewhat beyond the rudimentary sensing capabilities we ascribe to a Level II machine.

Table 5-2: Classification of Task That Robots Can Perform

1) Pure displacement
   - 1.1 load/unload machines
     - a) machine tool: deburring, drilling, grinding, routing
     - b) plastic materials forming and injection molding
     - c) metal die casting
     - d) hot forging and stamping
     - e) cold forging
     - f) furnace load/unload
     - g) cold sheet stamping
     - h) heat treatment
     - i) foundry: sand casting, investment casting
   - 1.2 parts manipulation (eg. packing, sorting, and conveying orientation)
   - 1.3 palletizing
2) Displacement and processing
   - 2.1 spot welding
   - 2.2 continuous welding
   - * 2.3 mechanical/electrical parts assembly
   - * 2.4 electronics parts assembly
   - 2.5 spray painting
   - 2.6 cabling
   - 2.7 cutting
   - * 2.8 other processing operations with portable tools
3) Displacement and inspection
   - * 3.1 dimensional control
   - * 3.2 other quality control functions

* Task requiring a Level II robot

Source: de Gregorio, 1980.

Table 5-3: ROBOT APPLICATIONS WITHIN THE AUTO INDUSTRY

Spot Welding	Casting Clean Up, Shake Out
Pedestal Welding	Machine Tool Loading\Unloading
Arc Welding	Conveyor Transfer
Stud Welding	Palletizing
Permanent Mold Casting	Plastic Molding
Die Casting	Paint Spraying
Press Transfer	Glass Handling
Forging	Dimensional Inspection
Heat Treatment	

Source: (Engelberger 80a)

irregular burr edges result in variable reaction forces. In the process of grinding, the motions required to achieve a smooth surface are also difficult to achieve. In order to solve these problems, a sensory feedback system with adequate sensitivity is required.

The loading and unloading of metal cutting machine tools in generally suitable for level I robots. The role of robots is usually restricted, however, to applications where production runs are too small for automatic transfer lines , but batch sizes are large enough to justify numerically controlled machine tools.[16] Recently, though, robots have also been integrated into transfer lines to move materials.

There are four major problems that are presently unsolved with regard to welding applications for level I robots:

- automatic magazining,
- clamping of parts to be welded,
- control over welding parameters (and quality),
- precise positioning of seams.

The problems listed above will gradually be surmounted by level II robots with the development of better sensory feedback, orienting, and magazining devices.

[16] As of 1978, slightly over 2% of all machine tools in the the metalworking industries were numerically controlled (AM 78). By one estimate NC machine tools still accounted for nearly 28% of the total output in these same industries (MIT 80).

Most existing assembly line jobs cannot be efficiently accomplished by Level I robots. The development of a flexible multi-purpose gripper,and additional sensing capabilities would alter the situation. According to Engelberger, president of Unimation Inc,the leading U.S manufacturer of robots, a flexible general purpose gripper would be a great boom to robotics. The lack of sufficiently flexible grippers,capable of dealing with a variety of geometries,leads to the inability of existing robots to pick up non-oriented parts. As sensing and manipulation capabilities are improved, assembly promises to be a very suitable task for robotization.

5.4 THE MANUFACTURING SECTOR

In 1979, manufacturing contributed nearly one quarter of the GNP, and accounted for nearly one quarter of total employment. (See Tables 5-4 and 5-5.) The proportion of GNP contributed by manufacturing hardly changed between 1970 and 1979. The proportion of employment in manufacturing fell several percentage points within the same 10 year period.

5.4.1 The Work Force

In 1979, nearly one third of the total workforce were blue collar workers. This includes skilled (craft and kindred), semi- skilled (operative), and unskilled (laborer) workers, as well as transportation equipment operators. These 32 million workers are distributed throughout manufacturing, the utilities[19], construction and mining. Fewer than half of these workers are in manufacturing.[20]

There are over eight million workers whose jobs would fit into the classifications given in Table 5-2. An breakdown of these workers in shown in Table 5-7.

5.5 DISTRIBUTION OF MANUFACTURING JOBS BY REGION AND STATE

5.5.1 Regional Overview

A comparison of the regional distribution of manufacturing employment clearly shows large variances in both the absolute numbers and relative proportions of manufacturing workers employed in the different regions of the country. From the viewpoint of the potential impacts of robots on the workforce, we focus our attention on:

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[19] This includes transportation services, communication services, power, water, and other utilities.

[20] In 1977, there were nearly 14 million production workers in all manufacturing, accounting for nearly 44% of all blue collar workers.

Table 5-4: CONTRIBUTION OF GNP BY MAJOR ECONOMIC SECTOR

	1970	1979
Total GNP (Billions of 1972 constant dollers)	1075.3	1431.6
SECTOR	Percentage of GNP	
Manufacturing	24.2	24.6
Wholesale and Retail Trade	16.6	17.0
Finance	14.2	15.5
Services	11.6	12.2
Government	14.1	11.8
Trans,Comm and Utilities	10.9	9.8
Construction	5.3	4.1
Agriculture	3.2	2.8
Mining	1.8	1.5
Rest of World	.1	.7

Source: (Statistical Abstract 80),Table 731.

Table 5-5: EMPLOYMENT BY MAJOR SECTOR

	1970	1979
Total employment	78,627,000	96,945,000
	Percent of Employment	
Manufacturing	26.4	22.8
Wholesale and Retail Trade	19.1	20.3
Finance	5.0	6.0
Services[17]	25.8	28.1
Public Administration[18]	5.7	5.2
Trans.,Comm., and Utilities	6.8	6.6
Construction	6.1	6.5
Agriculture,forestry,fisheries	4.6	3.6
Mining	.7	.9

Source: (Statistical Abstract 80),Table 679.

[17] Includes teachers and professors, and employees of government sponsored social service agencies.

[18] Includes workers uniquely involved in governmental activities,e.g. judicial and legislative.

Table 5-6: DISTRIBUTION OF TOTAL WORKFORCE BY MAJOR OCCUPATION GROUP, 1979

Total employment, all industries (persons 16 years and over)	96,945,000
Occupation Group	Percentage of Total employment
White collar workers	**50.9**
Blue collar workers	**33.1**
Craft and Kindred	13.3
Operative, except transport	11.3
Transport equip. operators	3.7
Non Farm Laborers	4.8
Service workers	**13.3**
Farmers and farm workers	**2.7**

Source: (Statistical Abstract 80), Table 696.

- Regions with highest total number of manufacturing jobs.
- Regions with highest percentage of total jobs which are in manufacturing.

A breakdown of manufacturing employment by region is shown in Table 5-8. The nine regions cover the continental United States, and roughly correspond to the ten region division used by the Bureau of Labor Statistics.[22] Three regions (including 17 states) account for nearly 60 % of total manufacturing employment. Almost one quarter of all manufacturing jobs are concentrated in the East North Central region (Ohio, Indiana, Illinois, Michigan and Wisconsin). In these states, manufacturing accounts for a large number of jobs, as well as a high percentage of total statewide employment.

5.5.2 Statewide Overview

The ten states with the largest manufacturing employment account for over 50% of the total manufacturing employment in the country. The 20 states with the largest manufacturing employment account for almost 80% of total manufacturing employment. These 20 states are shown in Table 5-9.

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[22] When regions are referred to by a geographic name, i.e. the East North Central Region, it refers to the division used in the reference for Table 5-8. When numeric designations are used, i.e. Region V, it refers to the standard BLS division of the country.

Table 5-7: BREAKDOWN OF SELECTED BLUE COLLAR WORKERS, 1979

Total Blue Collar Workers (total employed, 16 years and over)	32,066,000
Major Categories of Blue Collar Workers Within Manufacturing	
Craft and Kindred Workers	
Machinest and Job Setters	642,000
Metalcraft workers	649,000
Operatives	
Assemblers	1,289,000
Checkers, examiners, and inspectors	746,000
Cutting operatives, nec[21]	263,000
Packers and wrappers (except meat and produce)	626,000
Painters, mfg. articles	185,000
Precision machine operators	405,000
Punch and stamping press operators	158,000
Welders and flamecutters	713,000
Machine operatives	1,822,000
Laborers	
Freight and Material handlers	780,000
Total	8,278,000

Source: (Statistical Abstract 80), Table 697.

5.5.3 Percentage of Employees in Manufacturing

There are 21 states with more than 25% of their total nonagricultural employment concentrated in manufacturing. These states are shown in Table 5-10, along with those states with less than 10% concentration of manufacturing jobs to emphasize the differences in concentration of manufacturing employment within the country.

There are some interesting differences between the states which have large numbers and high percentages of manufacturing employees. California and New York have the largest numbers of manufacturing employees, but are not even among the states with 25% or more of their jobs in manufacturing. Rhode Island and Vermont, on the other hand, have a high percentage of their employees in manufacturing, even though they have comparatively few manufacturing jobs. There are several states which rank high on both list, including North Carolina, Indiana, Michigan and Ohio.

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[21] Not elsewhere classified

Table 5-8: REGIONAL BREAKDOWN OF MANUFACTURING EMPLOYMENT, 1979

REGION	PERCENTAGE OF NATIONAL MANUFACTURING EMPLOYMENT LOCATED WITHIN REGION
U.S.,Total	**100.0**
East North Central	24.5
Mid Atlantic	17.6
South Atlantic	14.6
Pacific	12.3
West South Central	7.8
N. England	7.7
West North Central	6.9
East South Central	6.8
Mountain	2.7

REGION	PERCENTAGE OF REGION'S EMPLOYMENT CONCENTRATED IN MANUFACTURING
U.S., average	**23.4**
East North Central	29.4
N. England	28.2
East South Central	27.4
Mid Atlantic	24.5
South Atlantic	21.4
West North Central	20.7
Pacific	20.0
West South Central	19.2
Mountain	12.7

Source: (Statistical Abstract 80), Table 691.

Table 5-9: THE 20 STATES WITH THE LARGEST NUMBER OF MANUFACTURING JOBS

States	Number of Employees in Manufacturing, 1979 (in thousands)
Total,U.S	21,081.7
1. California	2,018.0
2. New York	1,493.7
3. Pennsylvania	1,397.1
4. Ohio	1,382.8
5. Illinois	1,282.5
6. Michigan	1,134.9
7. Texas	1,033.0
8. North Carolina	822.9
9. New Jersey	792.6
10. Indiana	742.4
11. Massachusetts	658.4
12. Wisconsin	601.4
13. Tennessee	527.3
14. Georgia	526.4
15. Missouri	460.7
16. Connecticut	431.8
17. Florida	427.1
18. Virginia	413.7
19. South Carolina	398.4
20. Minnesota	392.1

SOURCE : EMPLOYMENT AND EARNING, U.S. DEPARTMENT OF LABOR. SEPT., 1980.

Table 5-10: STATES WITH HIGH AND LOW CONCENTRATIONS OF MANUFACTURING EMPLOYEES

STATE	% OF STATEWIDE EMPLOYMENT IN MANUFACTURING	MANUFACTURING EMPLOYEES, 1979 (in thousands)
NC	34.94	822.9
SC	33.84	398.4
IND	32.56	742.4
RI	31.81	126.3
MI	31.40	1134.9
CONN	30.70	431.8
OH	30.65	1382.8
WIS	30.38	601.4
NH	29.81	114.1
TENN	29.49	527.3
ARK	29.33	219.4
PENN	28.79	1397.1
MS	28.01	235.7
AL	27.42	375.6
DEL	27.31	71.3
ILL	26.01	1282.5
MA	25.83	110.3
VER	25.78	51.0
NJ	25.76	792.6
MASS	25.20	51.0
GA	25.00	526.4
New Mex	7.46	34.7
N Dak	6.73	16.7
Nevada	5.10	19.8
Wyoming	5.07	10.5
Dist. of Columbia	2.42	15.4

SOURCE : EMPLOYMENT AND EARNING, U.S. DEPARTMENT OF LABOR, SEPT., 1980.

5.6 INDUSTRIES SELECTED FOR STUDY

Industries within the manufacturing sector are typically classified by their major outputs. Industries which produce durable goods are grouped together as are industries which produce non-durables. At present, almost all industrial robots are used within a subset of the durable goods producers commonly referred to as the *metalworking sectors*. These include[23] the following industries (followed by their Standard Industrial Classification Code):

- Fabricated Metals (SIC 34)
- Machinery except Electrical (SIC 35)
- Electrical and Electronic Equipment (SIC 36)
- Transportation Equipment (SIC 37)

5.6.1 The Metalworking Sector

There are several reasons why we chose these four industries from among the 22 major industries classified in the SIC codes. These four industries comprise more than one-third of the nations total manufacturing jobs (Table 5-11), and more than one-third of the nations total production workers (Table 5-12). More important, nearly half of all operatives jobs-- including 90 % of assemblers and nearly 70 % of machinest-- are concentrated within these four industries, as shown in Table 5-13.

5.7 REGIONAL DISTRIBUTION OF METALWORKING EMPLOYEES

More than 50 % of the production workers in each of these four industries are localized within the five Great Lakes States plus New York and California, as shown in Table 5-14. Within these same states, the metalworking sector also employees a large percentage of total manufacturing workers. Table 5-15 shows that almost 70 % of the production workers in Michigan, and nearly 50 % of the production workers in Indiana, Wisconsin, and Ohio are concentrated in metalworking.

If robots are placed in existing plants, they will be used in those areas where there are large numbers of workers doing the types of jobs that robots can do. We would expect to see (and in fact, observe) a large number of robots being used in the Great Lakes states, particularly Michigan. California and New York would also be likely places to retrofit robots into existing plants.

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[23] A more complete designation of the metalworking sector would include metal furniture (SIC 25), primary metals (SIC 33), precision instruments (SIC 38) and miscellaneous manufacturing industries(SIC 39). Throughout the rest of this report, we restrict our definition of the metalworking sector to SIC codes 34-37.

Table 5-11: EMPLOYMENT IN THE METALWORKING SECTOR, 1977

	Total Employment	% of Total Manufacturing Employment
Manufacturing,total	19,721,350	100.0
SIC 34-37		
34 Fabricated Metal	1,588,640	8.1
35 Machinery, except Electrical	2,174,070	11.0
36 Electrical and Electronic equipment	1,882,730	9.5
37 Transportation Equipment	1,889,390	9.6
Total Metalworking	7,534,830	38.2

Table 5-12: PRODUCTION WORKERS IN THE METALWORKING SECTOR, 1977

	Number of Production Workers	% of Total Production Workers
Manufacturing,total	13,963,950	100.0
SIC 34-37		
34 Fabricated Metal	1,191,810	8.5
35 Machinery except Electrical	1,368,450	9.8
36 Electrical and Electronic equipments	1,201,160	8.6
37 Transportation equipment	1,330,380	9.5
Total Metalworking	5,091,800	36.4

SOURCE : BUREAU OF LABOR STATISTICS, OCCUPATIONAL EMPLOYMENT IN MANUFACTURING INDUSTRIES, 1977, U.S.DEPARTMENT OF LABOR, BLS BULLETIN 2057, MARCH, 1980.

Table 5-13: ESTIMATES OF PERCENT COVERAGE IN METALWORKING FOR SELECTED OCCUPATIONS

	Approximate Number workers in (1) Metalworking	Total Workers in All Manufacturing, 1979(2)	% Coverage in Metalworking
Total Workers in Sample	4,173,465	8,278,000	50.4%
Skilled Workers			
Machinists and Jobsetters and Metalcraft Workers and Unclassified Skilled Workers	477,200	1,291,000	(3)
Operative and Unskilled Workers	3,696,265	6,987,000	52.4%
Assemblers	1,178,520	1,289,000	91 %
Checkers, Examiners, Inspectors and Testers	280,050	746,000	37 %
Production Painters	74,380	185,000	40 %
Maintenance Painters	7,210		
Welders & Flamecutters	210,800	713,000	30 %
Packager	55,430	626,000	8.8%
Unclassified Unskilled Workers	310,700	1,043,000(4)	29.7%
Machine Operatives	1,579,175*	2,385,000**	66 %

[1] Taken from "Occupational Matrix for Selected Metalworking Operative Classes," which covers roughly 80% of production workers in metalworking.

[2] From Statistical Abstract, 1980, Table 697, Employed persons by Sex, Race and Occupation.

*Machine Operatives = Production workers enumerated in sample - [skilled workers + assemblers + inspectors and testers + painters + welders + packers + unclassified Unskilled Workers]

**Machine Operatives = [Machine operatives + punch and stamping press operatives + precision machine operatives]

[3] Many of the occupational titles not included in the "Occupational Matrix for Selected Metalworking Operative Classes" would fall into this category. Therefore, an estimate for the percent coverage in metalworking based on these figures would be misleading.

[4] Includes freight and material handlers, and cutting operatives, not elsewhere classified.

Table 5-14: STATES WITH LARGE NUMBERS OF PRODUCTION WORKERS IN METALWORKING[24]

34: Fabricated Metals

State	Production* Workers, 1977	% of U.S. total for SIC 34
1. Mich	114,690	9.6
2. Ill.	98,415	8.3
3. Calif.	93,570	7.9
4. N.Y.	60,270	5.1
5. Ind.	49,270	4.1
6. N.J.	45,160	2.8
7. Wis.	43,270	2.6
7 State Total:	504,645	42.3
U.S. Total:	1,191,810**	

35: Machinery, Except Electrical

State	Production* Workers, 1977	% of U.S. total for SIC 35
1. Ill.	142,166	10.4
2. Mich.	96,740	7.1
3. Calif.	90,975	6.6
4. N.Y.	77,640	5.7
5. Wis.	74,085	5.4
6. Ind.	54,272	4.0
7. N.J.	38,560	2.8
7 State Total:	574,538	41.0
U.S. Total:	1,368,450**	

36: Electrical & Electronic Machinery

State	Production* Workers, 1977	% of U.S. total for SIC 36
1. Calif.	109,166	9.1
2. Ill.	97,160	8.1
3. Ind.	89,404	7.4
4. N.Y.	77,860	6.5
5. N.J.	49,670	4.1
6. Wis.	35,725	3.0
7. Mo.	32,920	2.7
7 State Total:	491,905	42.0
U.S. Total:	1,201,160	

37: Transportation Equipment

State	Production* Workers, 1977	% of U.S. total for SIC 37
1. Mich.	293,770	22.1
2. Claif.	132,494	10.0
3. Ind.	80,797	6.1
4. N.Y.	54,480	4.1
5. Texas	36,810	2.8
6. Wis.	35,405	2.7
7. Mo.	32,960	2.5
7 State Total:	666,716	50.1
U.S. Total:	1,330,380**	

Total Metalworking

State	Production* Workers, 1977	% of U.S. total in SIC (34-37)
1. Mich.	536,970	10.5
2. Calif.	426,205	8.4
3. Ill.	365,171	7.2
4. Ind.	273,743	5.4
5. N.Y.	270,250	5.3
6. Wis.	188,485	3.7
7. N.J.	133,490	2.6
7 State Total:	2,194,314	43.1
U.S. Total:	5,091,800**	

*From OES Reports for Specific States. Ohio is not included. Figures are for all production workers. States which only list part of industry employment (Missouri and Texas) are noted in the footnotes to "Occupational Employment by Region for Selected Operative Classes."

**From Occupational Employment in Manufacturing Industries, 1977 (National figures include Ohio).

[24] See the footnotes in Table 5-15. Some of these numbers may significantly underestimate the number of production workers in metalworking in some of these states.

Table 5-15: PRODUCTION WORKER EMPLOYMENT WITHIN METALWORKING FOR SELECTED STATES

STATE	34	35	36	37	TOTAL	% of Mfg. Prod. Wkrs in 34-37
NY	60,270	77,640	77,860	54,480	270,250	28.2
NJ	45,160	38,660	49,670	---[25]	133,390	27.2
PA	16,610	14,080	---	4,470	35,160	3.8[26]
GA	15,240	13,000	11,400	23,940	63,5802	16.9
NC	17,410	24,120	30,340	7,210	79,080	12.9
IND	49,270	54,272	89,040	80,797	273,7432	52.5
Ill	98,415	142,1666	97,160	26,939	365,171	42.6
Mich	114,690	96,740	31,770	293,770	536,970	68.1
Ohio						49.0[27]
WIS	43,270	74,085	35,725	34,405	188,485	49.5
TX	11,120	11,370	---	36,810	59390	9.9[28]
MO	22,590	24,100	32,920	32,960	112,570	37.7
CALF	93,570	90,975	109,166	132,494	426,205	37.3

SOURCE: OCCUPATIONAL EMPLOYMENT STATISTICS REPORTS FOR MANUFACTURING EMPLOYMENT, 1977, FROM THE INDIVIDUAL STATES.

[25] Reports from County Business Patterns show there are large numbers of people employed in these industries. However, no listing was given in the state's Occupational Employment Statistics Report. Thus, the percentage estimates for New Jersey, Pennsylvania, and Texas are underestimates.

[26] Reports from County Business Patterns indicate that over 31 % of all manufacturing employees are located within metalworking.

[27] Based on reports from County Business Patterns for the number of manufacturing employees (not just production workers.)

[28] Reports from County Business Patterns indicate that nearly 40 % of manufacturing employees are concentrated in metalworking.

The survey results discussed in the previous chapter indicate that many users will continue to retrofit robots into current operations, but , in addition, they plan to put robots in new plants. New plant construction adds a great deal of complexity to the issue of social impacts. If most of the increase in robot use in the short term were due to new plant installations , it may not be the case that robots will primarily be used in those areas where there are *currently* a large number of production workers in metalworking industries. The whole notion of displacement itself would be questionable, since workers are always *added* to new facilities. On the other hand, if the opening of new plants resulted in the shutting down of older, less profitable facilities, their could be far more transitions in the workforce then one would imagine from looking at current employment statistics. These indeed are crucial considerations, but could not be investigated in this report. We still think that a knowledge of where there are large concentrations of workers who do the types of jobs that robots can do is useful for initiating policy discussions.

5.8 REGIONAL DISTRIBUTION OF WAGE RATES

The discussion on private industry's motivations for using robots in Chapter 4 highlighted the importance given to hourly wage rates. Within the set of tasks a robot is capable of doing, the occupations with higher wage rates will most likely be the first candidates for replacement. A sampling of regional figures for the average hourly wages for several occupations in SIC 35 are shown in Table 5-16. Some cities, such as Detroit, Cleveland, Milwaukee and Chicago pay significantly higher wages for a given occupation than others, such as Atlanta, or Denver. There are also large differences in the pay scale between the various occupations. Interestingly enough, many of the task performed by the highest paid occupation, tool and die makers, are generally agreed to be beyond the capabilities of Level I robots. So are most of the task performed by the lowest paid workers, class C assemblers.

The average weekly earnings of all manufacturing production workers (averaging wages of all occupations for all 22 SIC industries) is shown in Figure 8-3. The states with the highest and lowest weekly wages are highlighted in Figure 8-4. Based on wage considerations alone, there is most incentive to use robots in the Great Lakes region, and lest incentive to use them in Region IV, which includes most of the South Atlantic and South Central States.

Table 5-16: AVERAGE HOURLY WAGES BY OCCUPATION BY REGION

AVERAGE HOURLY WAGES BY OCCUPATION BY REGION (1977)
FOR SIC 35, MACHINERY EXCEPT ELECTRICAL

City & State / Occupation	New York NY	Buffalo NY	Houston TX	Dallas TX	Milwaukee WI	Detroit MI	Chicago IL	Atlanta GA	Los Angeles CA	Pittsburgh PA	Newark NJ	Boston MA	Denver CO	Cleveland OH
Filers, Buffers, Cleaners, Polishers	4.67	--	--	--	--	6.99	7.62	3.77	5.68	5.96	6.46	5.20	--	7.58
Inspector	5.95	7.20	7.37	6.48	7.24	7.79	7.43	5.75	6.74	7.37	5.95	5.26	6.67	7.20
Machinist - Production	6.09	6.74	7.73	6.56	--	--	--	5.95	7.42	7.09	6.83	6.69	--	6.12
Tool and Die Maker	7.45	7.85	7.72	7.00	8.25	9.15	9.07	6.81	9.01	7.39	7.56	6.87	6.19	7.60
Drill-Press or Boring Machine Operator	6.33	6.40	6.59	6.23	7.37	7.01	7.25	4.59	6.64	6.61	6.39	7.33	--	7.46
Grinding Operator	6.58	6.66	7.09	6.31	8.33	8.38	7.31	4.91	6.40	7.41	6.50	6.43	6.43	7.18
Lathe or Turning Machine Operator	6.38	6.50	7.10	6.51	7.73	7.40	7.25	5.10	6.53	6.75	6.20	6.63	6.61	6.88
Machine-Tool Operator - Class A	6.37	6.77	7.15	6.37	7.78	8.19	7.38	5.41	6.87	7.15	6.50	6.54	6.60	7.02
Machine-Tool Operator - Class B	5.16	6.28	6.66	5.07	6.89	7.01	6.51	4.59	5.45	6.71	6.59	6.01	5.36	6.01
Machine Tool Operator - Class C	4.02	5.44	4.89	3.56	5.25	5.48	5.90	--	3.96	6.15	4.85	4.71	5.04	4.12
Machine Tool Operator - Numerical	6.37	7.00	7.29	6.44	7.43	7.14	7.55	--	6.86	6.69	6.06	6.24	6.44	7.17
Punch-Press Operator - Class A	6.47	--	7.58	5.50	6.84	--	6.51	4.97	5.37	--	6.18	5.73	--	6.33
Punch-Press Operator - Class B	3.58	--	--	3.72	6.86	5.39	5.93	4.14	3.68	--	6.10	4.63	--	4.89
Welders, Hand - Class A	6.24	7.21	7.29	5.89	7.42	7.59	7.52	--	6.82	7.41	6.75	6.62	6.56	7.21
Welders, Hand - Class B	5.66	6.20	6.59	4.22	6.93	6.96	6.90	4.97	5.68	7.21	4.73	--	5.61	5.60
Welders, Machine - Class A	--	6.66	6.43	6.43	7.30	--	--	5.38	--	--	--	6.41	--	6.31
Welders, Machine - Class B	4.12	5.09	--	5.18	6.11	--	6.21	4.33	4.52	--	--	5.45	5.82	6.01
Assemblers, Class A	5.92	6.92	6.89	6.08	6.72	7.80	6.84	5.20	6.29	7.14	6.54	6.18	5.94	7.21
Assemblers, Class B	4.55	6.43	5.86	4.55	6.96	7.23	6.49	4.65	4.41	6.02	5.71	4.89	4.30	6.13
Assemblers, Class C	3.58	6.16	4.36	3.47	5.55	6.22	4.35	4.30	3.18	4.35	5.29	4.18	--	5.08
Electricians, Maintenance	7.08	7.38	7.66	6.36	8.25	8.77	8.15	6.00	7.76	6.49	--	--	--	7.88
Mechanics - Production	--	--	--	--	--	--	--	5.95	--	--	--	6.15	6.99	--

Source: Industry Wage Survey
Machinery Manufacturing
January 1978
B.L.S.

5.9 OCCUPATIONAL BREAKDOWN OF METALWORKING OPERATIVES

Over 80% of the production workers in metalworking are enumerated in Table 5-17. Most of those omitted are maintenance people and jobsetters, and other categories of skilled workers. The other broad occupational groups - assemblers, operative machinest, and other operative and unskilled workers- will collectively be referred to as operatives. All assemblers listed in the data sources are enumerated. Most, but not all of the workers in the other operative classes , are also enumerated. These figures indicate that operatives comprise nearly three quarters of all production workers in metalworking, which is nearly half of the total employment in this sector.

The occupational employment matrix is filled out for 14 states in Table 8-8. This type of employment data is collected under the Occupational Employment Statistics Program, which is briefly described in Table 8-6. This type of information is available from the Office of Research and Analysis of the state's Employment Security Agency.[29] A listing of these agencies is given in Table 8-9.

5.10 CLASSIFICATION OF JOBS BY SKILL REQUIREMENTS

The detailed occupational breakdowns shown in Table 5-17 are not sufficient for designating the types of jobs where robots could be substituted for humans. Even though we know that robots are often used in welding, or machine loading, we do not know what percentage of welding or machine loading task in a given industry are suitable for robotization. Even within a narrowly defined occupation, such as welding, there are a wide range of skill and physical requirements that depend on the physical properties of the product, and the production environment. The percentage of jobs of a given type that could be robotized depends on how the various types of welding task are distributed over the range of physical and skill requirements.

Several factors which relate directly to the actual performance of the job could be used to assess the potential for robotization. An analysis of specific jobs should address the following issues:

- What tasks workers are required to perform?
- What machines, tools, equipment, or other aids are used?
- What materials, products, subject matter, or services are involved?

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[29] A comprehensive overview of available labor market data is given in Jobs in the Private Sector: Use of Labor Market Information. U.S. Dept. of Labor, Employment and Training Administration, Division of Labor Market Information. Monograph # 2. October, 1980.

Table 5-17: OCCUPATIONAL MATRIX FOR SELECTED METALWORKING OPERATIVE CLASSES, NATIONAL TOTALS, 1977

(Summary)

OCCUPATION	SIC: 34	35	36	37	Total Metalworking
Skilled Workers	175,710	149,200	64,240	88,050	477,200
Assemblers	135,120	265,950	472,230	305,220	1,178,520
Operative Machinist	157,650	403,110	99,150	172,740	932,650
Other Operatives and Unskilled Workers	448,345	242,900	293,810	500,040	1,585,095
Production Workers Enumerated Above	1,016,825	1,061,160	929,430	1,066,050	4,173,465
Total Production Workers in Metalworking	1,191,810	1,368,450	1,201,160	1,330,380	5,091,800
% - Coverage of Sample	85%	78%	77%	80%	82%

*Includes most but not all of occupational titles listed in Occupational Employment in Manufacturing, 1977, dis. Dept. of Labor, Bureau of Labor Statistics, March 1980 Bulletin 2057.

SKILLED WORKERS*	SIC:	34	35	36	37	Total Metalworking
Die Setter		1,880	--	--	--	1,880
Die Sinker		1,210	--	--	--	1,210
Lay-out Marker, Metal		9,070	4,850	--	2,760	16,680
Machine-Tool Operator-- Tool Room		5,040	11,610	5,080	11,680	33,410
Millwright		7,670	5,180	3,810	11,410	28,070
Machine Tool Setter		8,780	15,670	6,690	--	31,140
Punch Press Setter		7,540	2,930	2,950	--	13,420
Sheet Metal Worker		20,710	20,730	6,900	16,610	64,950
Tool & Die Maker		29,750	54,960	17,030	20,160	121,900
Unclassified Skilled Craft and Kindred Workers		25,200	33,270	21,780	25,430	105,680
Total Skilled Workers		175,710	149,200	64,240	88,050	477,200

*Includes most, but not all, occupational titles in Occupational Employment in Manufacturing, 1977.

ASSEMBLERS	SIC:	34	35	36	37	Total Metalworking
Assembler--A		15,860	10,950	20,280	19,530	66,670
Assembler--B		34,470	26,040	37,580	24,930	123,020
Assembler--C		84,790	101,820	275,030	214,200	675,840
Assembler--A Electrical & Electronic		--	14,210	27,710	4,560	46,480
Assembler--B Electrical & Electronic		--	29,970	80,140	5,240	115,350
Assembler--A Electro-Mechanical		--	5,450	7,710	2,120	15,280
Assembler--B Electro-Mechanical		--	12,590	7,000	5,070	24,660
Assembler--A Machine		--	40,910	6,440	3,320	50,670
Assembler--B Machine		--	24,010	10,340	7,270	41,620
Assembler--B Aircraft Structure & Surface		--	--	--	18,980	18,980
Total Assembler		135,120	265,950	472,230	305,220	1,178,520

OPERATIVE MACHINIST* SIC:	34	35	36	37	Total Metalworking
Diecasting Operator and/or Setter	1,490	1,670	3,370	--	6,530
Drill Press and/or Boring Machine Operator	22,180	50,350	11,710	19,810	104,050
Forging Press Operator	4,510	--	--	1,990	6,500
Forging and/or Straightening Roll Operator	1,000	--	--	--	1,000
Gear Cutting/Grinding and/or Shaping Machine Operator	--	6,210	1,260	3,600	11,070
Grinding and/or Abrading Machine Operator	21,450	49,410	6,330	19,900	97,090
Lathe and/or Turning Machine Operator	28,930	69,040	10,810	21,480	130,260
Machinist	23,540	58,560	14,090	16,560	112,750
Machine-Tool Operator-- Combination	25,760	70,580	14,340	32,070	142,750
Machine Tool Operator-- Numerical Control	3,970	26,690	5,570	5,670	41,900
Milling and/or Planing Machine Operator	5,510	36,940	3,420	12,980	58,400
Power Brakes and/or Bending Machine Operator	17,350	7,260	2,670	5,960	33,240
Punch Press Operator	84,480	22,110	23,640	29,660	159,890
Roll Forming Machine Operator	4,320	--	--	--	4,320
Shearing and/or Slitter Machine Operator	13,160	4,290	1,940	3,060	22,900
Total Machinist (Operative)	257,650	403,110	99,150	172,740	932,650

*Includes most, but not all, occupational titles in Occupational Employment in Manufacturing, 1977.

OTHER OPERATIVES AND UNSKILLED WORKERS*	SIC: 34	35	36	37	Total Metalworking
Conveyer Operator and Tender	1,840	1,690	7,350	7,190	
Coil Winder	--	2,210	24,360	--	
Dip Plater	4,120	--	3,660	--	
Electroplater	14,570	1,820	8,720	2,240	27,350
Filer, Grinder, Buffer, Chipper, Cleaner and/or Polisher	25,400	21,970	6,480	23,510	77,360
Heat Treater Annealers and/or Temperer	4,210	4,920	1,480	4,160	14,770
Helper, Trader	21,370	7,110	2,280	9,230	
Inspecter	37,660	50,370	64,280	76,220	228,580
Laminators, Preforms	--	--	--	10,160	
Mixer and/or Blender of Chemicals	--	--	2,700	--	
Order Filler	5,790	7,340	6,450	4,280	
Painters, Maintenance	1,320	1,770	1,390	2,730	7,210
Painters, Production	19,830	14,020	10,000	30,530	74,380
Plater Helper	14,510	--	3,920	--	
Production Packager	26,300	7,400	16,500	5,230	55,430
Rigger	1,720	1,710	--	3,520	
Riveter, Light	1,890	2,410	2,410	2,380	
Riverter, Heavy	--	--	--	1,320	
Sandblast and/or Shot Blaster	3,310	2,980	--	--	
Tester	6,760	8,150	26,540	10,020	51,470
Total Welder	89,120	3,520	16,100	102,060	210,800
Welder & Flamecutter--a	24,600	1,560	4,410	18,940	49,510
Welder & Flamecutter--b	46,780	1,540	5,480	54,380	108,180
Welder & Flamecutter--c	17,740	420	6,210	28,740	53,110
Wirer, Electric	--	--	22,940	--	
Unclassified Semiskilled Workers	64,620	62,670	89,940	106,660	
Unclassified Unskilled Workers	101,620	58,840	76,260	73,980	310,700
Total Operative & Unskilled Workers	448,345	242,900	393,810	500,040	1,585,095

*Includes most, but not all, occupational titles in Occupational Employment in Manufacturing, 1977.

- Amount of independent judgement that must be exercised.

5.10.1 Physical and Mental Requirements

A logical starting point is to identify the specific operative tasks involved in the performance of each job. Each task can then be examined to ascertain the physical and mental requirements. We adopt the classification system devised by the the Department of Labor, which is explained in the The Dictionary of Occupational Titles (DOT 77) and supplemental publications.[30]

The physical demands of a job serve as an expression of both the physical requirements of the jobs and the physical capacities (specific physical traits) which a worker must possess to meet these requirements. Within this classification system, the physical demands of a job are divided into six areas:

- strength,
- climbing/balancing,
- reaching, handling, feeling, and fingering,
- talking/hearing,
- stooping, kneeling, crouching, or crawling,
- seeing.

Each of these factors is subdivided further to express the specific physical functions of the worker. For example, seeing is broken down into major visual functions such as:

- depth perception
- field of vision
- acuity (far and near)
- accommodation
- color vision

to give additional clarity to the specific visual requirements of a job.

The environmental conditions, or the physical surroundings of a worker, is a major factor in the classification of jobs. A particular job may be undesirable or even dangerous as a

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[30] See Handbook for Analyzing Jobs, U.S. Dept. of Labor, Manpower Administration, 1972, and Selected Characteristics of Occupations Defined in the Dictionary of Occupational Titles, U.S. Dept. of Labor, 1981.

result of the work environment. Environmental conditions are divided into seven categories in the Department of Labor classification:

- location (inside, outside, or both)
- extremes of cold
- extremes of heat
- wet and humid
- noise and vibration
- fumes, odors, toxic conditions, dust, poor ventilation
- hazards

Other factors to be considered in the classification of jobs are the minimum levels of mathematical and language development which are required to successfully preform the job as well as the specific vocational preparation (training time) necessary to learn the techniques, acquire information, and develop the facilities necessary for satisfactory performance in a specific job-worker situation. The type of vocational preparation and training time associated with each job may give some indication of how difficult it will be to apply the robot to the job. This is particularly important in considering the level of computational power which is required as well as the relative set up times for the robot.

A characterization of jobs according to physical demands and environmental conditions serves a dual purpose. First, a correlation can be drawn between the capabilities of a robot and the requirements of the job. Second, this information can be used to determine in which jobs the introduction of robots would be particularly desirable. Jobs which are dangerous, monotonous, or physically discomforting are desirable applications for robots from both the management and worker viewpoints.

Table 5-18 shows how an occupation may be analyzed for it distribution in skill requirements to facilitate an assessment of robot applicability. There are over 100 separate listings for inspectors in the Dictionary of Occupational Titles. Many of these inspection task vary with respect to the product being examined, but are similar in terms of the physical and mental skills required. The large number of inspectors are grouped into one of three aggregate categories based on skill level differences. The numbers in the first column represent the eight skill level classification used in the DOT. The most complex task are assigned level 0, and the simplest task are assigned level 7. Definitions of each level are contained in Table 8-10.[31] Each worker is classified by the most complex task

[31] See the Dictionary of Occupational Titles 4th edition, 1977, U.S. Dept. of Labor, pages 1369-71.

preformed. It is assumed that if the job requires it, the worker can preform one of the higher numbers (lower complexity) functions. Supplemental information regarding the physical demands of the job, environmental conditions, and training times is also given.

Inspection task at the bottom of the table (i.e. checking to see if labels on cans are straight) are within the capabilities of robot systems, whereas task at the top of the table (i.e. test driving a car) are not. Unfortunately, it is extremely difficult to obtain data on how operatives within a given job title are distributed over skill classifications. In a few cases, such as assemblers, the occupational title is often subdivided by the final product they work on (electro mechanical vs electronic), and by the length of the training time (Class A vs Class B vs Class C). This still does not give an adequate description of skill and physical requirements, or of environmental conditions, which are essential to know if we are to estimate the extent to which robots could possibly be used within different operative task.

5.11 ASSESSMENT OF POTENTIAL ROBOTICS APPLICATIONS AND ROBOT CAPABILITIES

5.11.1 Description of Survey

An effort was made to determine the potential for robotization within various occupations. Surveys were sent to all member firms of the Robot Institute of America.[32] The recipients of the survey were all current or potential users of robots. The firms ranged from small custom shops of fewer than 100 employees to large corporations with over 10,000 production workers. Most respondents were in sectors SIC 34-37.

The questionnaire shown in Table 8-11 asked firms to indicate the percentage of the jobs in each skill level (0-7) that could be performed by a robot with rudimentary sensory capabilities. Results of this questionnaire are shown in Table 5-19. The percentage estimates give an indication of how applicable robots with rudimentary sensing capabilities *may* be within task that fall within these eight skill classifications. Level II robots are not yet commercially available , so none of the respondents actually know the extent to which different task could be robotized with the first generation of sensor based machines. Nonetheless, respondents indicated that a significant number of task involving manipulation, tending , feeding , and handling could be done with Level II robots.

A supplementary survey was used to estimate what percentage of jobs within a given occupational title could be robotized. The survey is shown in Table 8-12. A list of 28

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[32] The survey is described in more detail in Chapter 4.

Table 5-18: A BREAKDOWN OF THE WORK REQUIREMENTS OF AN INSPECTOR

INSPECTORS

SKILL LEVEL	JOB SKILL REQUIREMENTS	PHYSICAL DEMANDS	ENVIRONMENTAL CONDITIONS	SPECIFIC VOCATIONAL PREPARATION
0				
1	reasoning ability	max. lift of 25 lbs. reaching, handling or feeling	inside(protected from weather conditions)	> 1 year
	sense of hearing	hearing, seeing		< 2 years
2				
3				
4	visual inspection, determine which component of a system is the source of the defect	lift max. of 50 lbs. reading, handling, feeling, seeing	inside(protected from weather)	> 6 months < 1 year
5				
6				
7	verify dimensions, visual inspection	max. lift of 25 lbs. reaching, handling, feeling, seeing	inside(protected from weather	> 30 days < 6 months

Table 5-19: ESTIMATES OF ROBOT USE WITHIN THE RANGE OF WORKER COMPLEXITY LEVELS

SKILL LEVEL	RANGE OF RESPONSE	RESPONSE OF MAJORITY OF FIRMS
0 Set up	0%	0%
1 Precision work	0-2 %	0%
2 Operate	0-75 %	15%
3 Drive	0-50 %	15%
4 Manipulate	10-90 %	25%
5 Tend	0-90 %	25%
6 Feed	20-100 %	45%
7 Handle	10-75 %	35%

Source: CMU Robotics Survey, April, 1981.

manufacturing occupations which are common to most or all of the industries in SIC's 34-37 and which appear to have possibilities for robotics applications were included in the survey. Each firm was requested to estimate the percentage of jobs within each occupation that could be performed with a level 1 or level 2 robot. We did not ask them to distinguish between cases where robots are retrofitted into existing facilities, and where new lines or plants are built to take full advantage of robotic capabilities. We assume that practically all respondents answered the survey with respect to retrofitting robots. Once again, respondents can not be expected to have precise notion of the capabilities of Level II robots. The cover letter accompanying the survey emphasized that we wanted an estimate of the percentage of jobs which *could* be robotized, acknowledging that robots will not be used in every task where they could be used. In follow up interviews, some respondents said they thought it was difficult and somewhat unrealistic to make the distinction between the jobs where robots could be used, and the jobs where it is economically justifiable to use them. We can not really say whether these estimates are an upper bound on *perceived* robot applicability, or an estimate of the percentage of jobs where it could be economically justifiable to use them.

The responses to the occupational title survey were off the cuff estimates, of sorts. As far as we know, respondents did not go through any formal analysis of the skill content and physical requirements of the job in preparing their estimates. However, all respondents were either robot users, or in the process of evaluating robot applications. It is fair to say

that while the estimates are rough approximations, they represent the best judgements of people who are knowledgeable about robot capabilities and production requirements.

5.11.2 Comments on Surveys

An initial lack of response to the survey prompted a campaign of telephone calling to determine why firms were not responding. This follow up raised many interesting points as to why this particular type of questions was so difficult to answer. Many firms were just entering the field , and were testing robots in a few limited applications. They have not yet considered the full range of potential applications. A general impression that emerged is that many of these firms lack the initiative to conduct the necessary research, and are relying upon the "pioneering" users - the auto makers, the aerospace firms, and several large capital goods manufacturers - to determine what applications are most suitable for robotics. Of the firms that have done extensive research on potential applications of robots, almost all consider this information to be confidential and are reluctant to discuss their results. This is a very sensitive subject and many firms are reluctant to discuss this type of information for fear of the backlash which could occur as a result of "mis-quotes".

5.11.3 Results and Analysis

The responses to the survey were quite varied, reflecting the different requirements of similar jobs in various industries. Each firms response is a function of many unique factors, as discussed earlier including the firms product , size of production run, and the production environment. A summary of the survey results is given in Table 5-20. The range of responses as well as a weighted average response is given. The weighted average response is a function of the responding firms size and yields a more realistic estimate of the percentage of operatives within a given occupational title that could be replaced with a robot.[33]

There are a few observations worth noting on the relation between firm size and the estimates of the percentage of operatives that could replaced with robots. The responses at the extremes of the range were generally those of the smaller firms, while the responses of the large firms tended to be centrally located within the range. There appear to be reasonable explanations for this. The advantages of a robot can not be properly utilized if the production run is too small, which is often the case in small firms. Also,

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[33] The results shown in Table 5-20 are based on 16 responses. Additional responses have been received, but not processed. Respondents were classified into one of six size classes. The weighted average was formed by multiplying the percentage response by a weighting factor derived from the size classification.

Table 5-20: ESTIMATES OF ROBOT USAGE WITHIN MAJOR OPERATIVE CLASSES

OCCUPATION	% OF JOBS WHICH COULD BE DONE BY LEVEL I ROBOTS		% of JOBS WHICH COULD BE DONE BY LEVEL II ROBOTS	
	Range of Responses	Average Weighted Response	Range of Responses	Average Weighted Resp
Inspector	5-25 %	13 %	5-60 %	35 %
Tester	1-10 %	8 %	5-30 %	12 %
Assembler	3-20 %	10 %	20-50 %	30 %
Caster	5-15 %	5 %	10-20 %	10 %
Coiler/Winder	15-40 %	24 %	15-50 %	40 %
Conveyor Operator	10-50 %	16 %	20-65 %	25 %
Packager	1-40 %	16 %	2-70 %	41%
Order Filler	5-20 %	12 %	5-80 %	32 %
Mach. Tool Op.-Non NC	10-30 %	15%	5-60 %	30 %
Mach. Tool Op.-NC	10-90 %	20 %	30-90 %	49 %
Welder/Flame-cutter	10-60 %	27 %	10-90 %	49 %
Filers/Grinder/Buffer	5-35 %	20 %	5-75 %	35 %
Production Painter	30-100 %	44 %	50-100 %	66 %
Mixer	5-10 %	10 %	5-10 %	10 %
Sandblaster/Shotblaster	10-100 %	35 %	10-100 %	35 %
Millwright	0-15 %	1 %	0-15%	1 %
Oiler	---	0 %	---	0 %
Rigger	---	0 %	---	0 %
Pourer	5-20 %	10 %	10-30 %	24 %
Kiln/Furnace Operator	0-10 %	2 %	0-20 %	15 %
Tool and Die Makers	1-5 %	3 %	4-60 %	50 %
Electro-Plater	5-40 %	20 %	5-60 %	55 %
Dip Plater	20-100 %	40 %	50-100 %	77 %
Etcher/Engraver	15-100 %	29 %	15-100 %	90 %
Heat treater/Annealer	5-50 %	10 %	5-90 %	46 %
Drill Press Operators	25-50 %	30 %	60-75 %	65 %
Grind/Abrad/Cutting	10-20 %	18 %	20-100 %	50 %
Lathe/Turning Mach. Op.	10-20%	18%	40-60%	50%
Mill/Plane Mach. Op.	10-20 %	18 %	40-60 %	50 %
Riveter	5-100 %	15 %	100 %	30 %
Punch Press Op.	10-100 %	40 %	60-80 %	70 %
Electronic Wirer	0-10 %	9 %	10-50 %	28 %

Based on a total of 16 responses.
All respondents did not give estimates for all occupations.

SOURCE:CMU ROBOTICS SURVEY. APRIL, 1981.

large firms tend to employ operatives in most or all of the different skill levels, whereas a small firm may employ only those operatives in one particular skill level. If this happens to be a low skill level, then the firm would have a high potential for robotization. If, on the other hand, this happens to be a high skill level, the firm would have a low potential for robotization. Another observation which was made is that the large firms realize the potential for robotization within many different occupations whereas, the small firms only realize the potential within a few select occupations. This suggests that the greatest users of robots will be large firms, an observation supported by the results of the Industry Policy Survey in Chapter 2.[34]

5.11.4 Prime Candidates for Robotization

We have singled out several occupational titles which survey respondents indicated had a high potential for robotization.[35] These occupational titles are subdivided into two categories:

- Prime operative task for Level I robots
- Prime operative task for Level II robots

The prime operative tasks are shown in Tables 5-21 and 5-22.

The prime areas of application as determined from the survey are in agreement with the results of other studies that have been conducted. There is, however, a large variation in the estimates of the percentage of operatives jobs that could be robotized, and the average responses tend to be somewhat lower than most forecasts. Apparently, these estimates represent industry user estimates of the extent to which given occupations may be robotized in existing plants. Forecast of eventual 100% application in several operative task such as assembly and inspection are only reasonable with the proviso that the entire manufacturing process is restructured to accommodate robots, not humans. It is highly improbable that this level of usage could ever be attained in existing manufacturing facilities, where robots are retrofitted into existing production processes.

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[34] Private conversations with four robot manufacturers support our observations that most establishments which use robots are large (500 or more direct production employees). However, one manufacturer pointed out that current sales are skewed towards large establishments because of the large percentage of sales to the auto industry. He said that as this market saturates, the proportion of sales to smaller firms will undoubtedly increase in future years.

The distribution of metalworking employees by size of establishment is given in Table 8-1.

[35] This is by no means an exhaustive list. For example, several important robot applications such as loading and unloading die casting machines were not included in the survey. This is due to oversight. Occupations such as dip platers, sandblasters/shotblasters and etchers/engravers also had high estimates, but were not singled out since relatively few people do these types of jobs.

Table 5-21: PRIME OPERATIVE TASKS FOR LEVEL I ROBOTS

Occupational Title	Average Response for Level I Robots	Average Response for Level 2 Robots
Production Painters	**44%**	**66%**
Welder/Flamecutters	**27%**	**49%**
Machine tool operators[36]	**20%**	**50%)**
Machine Operators (NC)	20%	49%
Drill Press Operators	18%	65%
Grinding/Abrading Ops	18%	50%
Lathe/Turning Operators	18%	50%
Milling/Planing Operators	18%	50%
Machine Operators (Non NC)	15%	30%

Table 5-22: Prime Operative Task for Level II Robots

Occupational Title	Average Response for Level I Robots	Average Response for Level II Robots
Electroplaters	**20%**	**55%**
Heat Treaters	**10%**	**46%**
Packagers	**16%**	**41%**
Inspectors	**13%**	**35%**
File/Grind/Buffers	**20%**	**35%**
Assemblers	**10%**	**30%**

[36] Machine tool operators includes the separate types of machinest listed below. These estimates are used as an average to approximate the percentage of all categories of machinest listed below which could be robotized.

5.11.5 Estimates of the Number of Operative Task Robots Could Do

As stated earlier, knowing both the general types of task which robots can do, and the number of manufacturing workers who do these types of task is still not sufficient for roughly approximating the number of operatives that *potentially* could be replaced by robots. The missing variable is a realistic estimate of the extent to which robots could be used within a given job situation. We have gathered these types of estimates, and have emphasized the their somewhat crude and approximate nature. Acknowledging the limitations of the data, we still feel it is reasonable to use these results to weight occupational employment data on the state and national level in order to estimate the potential for robotization by occupational type. We feel the justification for publishing such preliminary estimates is the absolute lack of useful information that is publicly available on the subject.

The purpose of estimating the number of operatives whose task *could* be replaced is to get a feeling for how many people will be involved in "first order adjustment processes", even though we have no idea of of how many of these adjustments will involve upgradings and improved opportunities, and how many will result in long term hardships. From a policy viewpoint, an estimate of the total number, and the geographic distribution of people who could be involved in so called "first order" adjustments will help us gauge if our existing institutions and policy mechanisms have the capacity, or capability to facilitate such changes.

The next series of tables give the employment figures for operatives in SIC 34-37 within those occupations that were identified earlier as prime operative task for robotization. The figures are given for fourteen states, and for the nation. Next to the employment figures are estimates of the number of jobs which could be done by Level I and Level II robots. These estimates are derived by multiplying the employment figure by the average weighted survey response for the particular occupational title. We assume that these percentages are equally applicable in all states, and in all four industries in the metalworking sector.[37]

Nearly three quarters of the metalworking workers employed in the three occupations designated as the prime operative task for Level 1 robots are machinest.[38] Nearly half of

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[37] As of today, robots are not equally distributed throughout all four industries. There is a disproportionate concentration in SIC 37, and in large establishments in general. In the years to come, however, it seems reasonable to assume that robots will be widely used within all four industries by both small and large establishments.

[38] The employment figures for major categories of machine tool operators are given in Table 5-23. The totals for the six separate listings of machinest are then used as the employment figure for Machine Tool Operators in Table 5-24.

the one million workers employed in these three occupational categories are concentrated in the Great Lakes states, plus New York and California. The story is much the same for the occupations designated as the prime operative task for Level II robots. One occupation, assemblers, accounts for nearly three quarters of these workers. Nearly 40 % of the 1.5 million workers in these six occupations are concentrated in the Great Lakes States, plus New York and California. The totals in Tables 5-21 and 5-22 are summarized and combined in Table 5-26. There are nearly three million workers employed in the nine occupations designated as the prime operative task for Level I and Level II robots in SIC 34-37 nationwide. Over 40 % of these workers are concentrated in the Great Lakes States , plus New York and California. If the data for Ohio were available, close to one half of these workers would be concentrated in the same area. Even without considering the estimates of the percentage of operative task that could be robotized, it seems reasonable to say that substantial numbers of labor force transitions will be occurring in the states mentioned above.

The summary figures for the number of jobs which could be done by robots is also given in Table 5-26. Halfing and doubling the estimates of the number of jobs that could be robotized by Level I and Level II robots would approximately bracket the average response within the low and high estimates.[39] Our estimates suggest that Level I robots could perform roughly 16 percent of the jobs within the nine categories of occupations designated as prime candidates for robotization. This could range between 8 and 32 percent. The estimates also suggest that roughly 40 % of these jobs could be replaced by Level II robots. This could range between 40 and 80 percent. Based on the average responses of the percent of jobs which robots could do, nearly one half million of the operatives within the designated occupations within SIC 34-37 could be affected "in a first order way" by the increased use of industrial robots. The figure roughly doubles to one million people for Level II robots.

The total employment in the nine occupations designated as prime candidates accounts for nearly three quarters of the operatives in metalworking, and metalworking operatives account for nearly one half of all operatives in manufacturing.[40] So the estimates given above only cover a subset of the manufacturing operatives whose jobs could be done by

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[39]We are mainly concerned with the estimates for machinest and assemblers, since these two occupations make up over three quarters of the workers in the selected groups. For assemblers, the assumption that the average response is twice the low estimate and half the high estimate holds reasonably well. The average Level I response used for machinest is 20%, and the average Level II response used is 50 %. The assumption of the average response being half the high response is an overestimate for some of the machinest included in the analysis. Nonetheless, the "twice-half" rule for bracketing the average estimates seems to be a reasonable simplification, considering the rather imprecise nature of the original estimates.

[40]See Table 5-13

robots. A rough estimate of the number of jobs that robots could do in all manufacturing is given in Table 5-27. These totals are roughly three times as large as the totals for metalworking. Based on the average response of the percentage of jobs which robots could do in metalworking, and extending these results to all manufacturing, Level I robots could possibly replace over one million operative jobs, and Level II robots could possibly replace nearly three million operatives. Again, these estimates roughly range from one half to twice the average numbers given.

5.11.6 Conclusions

Nearly seven million manufacturing production workers (nearly 7% of the total workforce) do the types of jobs which currently are, or soon will be, in the domain of industrial robots. But robots can not do all of these task in the foreseeable future, especially, if they are retrofitted into existing facilities. More realistically , robots which are commercially available today could possibly perform nearly 16 percent of operative task within those manufacturing operations where robots are well suited (with estimates ranging between 8 and 32 percent), sensor based robots could possibly perform 40 percent of these operative task (with estimates ranging between 20 and 80 percent). In the short term, maybe as many as two percent of the entire workforce could possibly be replaced by robots. With the next two decades, maybe this number will increase to 4 percent. This is hardly catastrophic on the national scale, especially when one allows for new job opportunities that will inevitably be created. But adjustments made in response to the rapid diffusion of this new technology may be intensified in those areas where certain types of manufacturing operatives are concentrated.

Table 5-23: EMPLOYMENT OF MAJOR CATEGORIES OF MACHINE TOOL OPERATORS

EMPLOYMENT OF MAJOR CATEGORIES OF MACHINE TOOL OPERATORS
IN METALWORKING, 1977[1]

State	Machine Tool[2]	Drill Press Boring	Grinding/ Abrading	Lathe/ Turning	Milling/ Planing	Punch Press	Total
NY	14,140	6,120	6,200	8,340	4,260	8,240	47,300
NJ	9,600	3,010	3,720	3,940	1,480	5,450	27,200
PA	3,140	960	1,170	1,600	960	920	8,750
GA	5,440	570	790	1,010	370	2,600	10,780
NC	10,010	1,600	950	1,380	620	1,260	15,820
TN	2,450	900	420	710	520	3,080	8,080
IN	14,275	6,805	5,400	7,879	2,043	10,313	46,915
IL	22,326	12,193	7,904	11,483	4,164	15,735	73,805
MI	31,050	14,180	13,000	11,950	5,980	31,120	107,280
OH							
WI	12,395	5,435	3,670	6,695	2,295	6,505	36,995
TX	3,510	1,070	900	2,450	900	540	9,370
MO	3,510	1,840	960	1,860	480	3,320	11,970
CA	33,595	6,687	7,937	9,649	4,321	3,360	65,549
13 State Total	165,441	61,370	53,321	68,946	28,393	92,343	469,814
U.S. Total[3] for Metalworking	330,810	104,050	97,090	130,260	58,400	159,840	880,450

[1]Figure taken from Occupational Employment Survey Reports for individual states for SIC 34-37.

[2]Machine Tool includes: Machinist, Machine tool operator, Combination machine tool operator, Numerical control machine tool operator - tool room.

[3]Figures taken from Occupational Employment in Manufacturing Industries, 1977 for SIC 34-37.

PRIME OPERATIVE TASKS FOR LEVEL I ROBOTS[1]

State	Production Painters			Welders/ Flamecutters			Machine Tool Operators			Totals		
	Employment	Number of Jobs Doable by[2]		Employment	Number of Jobs Doable by		Employment	Number of Jobs Doable by		Employment in 3 categories	Number of Jobs Doable by	
		Level I	Level II		Level I	Level II		Level I	Level II		Level I	Level II
		45%	65%		25%	50%		20%	50%			
NY	3,460	1,557	2,249	11,920	2,980	5,960	47,300	9,460	23,650	62,680	13,997	31,859
NJ	1,670	752	1,082	4,720	1,180	2,360	27,200	5,440	13,600	33,590	7,372	17,046
PA	320	144	208	3,170	793	1,585	8,750	1,750	4,375	12,240	2,687	6,168
GA	1,310	590	852	5,470	1,368	2,735	10,780	2,156	5,350	17,560	4,113	8,977
NC	980	441	637	4,110	1,028	2,055	15,820	3,164	7,910	20,910	4,633	10,602
TN	960	432	624	2,080	520	1,040	8,080	1,616	4,040	11,120	2,568	5,704
IN	2,956	1,330	1,921	11,207	2,802	5,604	46,915	9,383	23,457	61,078	13,515	30,982
IL	5,042	2,269	3,277	20,414	5,104	10,207	73,805	14,761	36,903	99,261	22,133	50,387
MI	6,810	3,065	4,427	30,010	7,503	15,005	107,280	21,456	53,640	144,100	32,023	73,072
OH												
WI	2,665	1,199	1,732	16,830	4,208	8,415	36,995	7,399	18,498	56,490	12,806	28,645
TX	1,320	594	858	5,930	1,483	2,965	9,370	1,874	4,685	16,620	3,951	8,508
MO	1,820	819	1,183	7,120	1,780	3,560	11,970	2,394	5,985	20,910	4,993	10,728
CA	6,670	3,002	4,335	22,969	5,742	11,485	65,549	13,110	32,775	95,188	21,854	48,595
13 State Total	35,983	16,192	23,389	145,950	36,491	72,967	469,814	93,963	234,909	651,747	146,645	331,273
U.S. Total Metal-Working	74,380	33,471	48,347	210,800	52,700	105,400	880,450	176,090	440,225	1,165,630	262,261	593,972

[1]State employment figures taken from Occupational Employment Statistics, 1977, for SIC 34-37.

[2]Estimates of percentage of operatives tasks which could be done by Level I and Level II robots taken from survey results. Percentage estimate used here is the weighted average response. Estimates all rounded to the nearest multiple of five.

Table 5-24: PRIME OPERATIVE TASK FOR LEVEL I ROBOTS

PRIME OPERATIVE TASKS FOR LEVEL II ROBOTS[1]

State	Electro-Platers			Heat Treaters			Packager			Filing/Grinding Buffer		
	Employment	Number of Jobs Doable by[2]		Employment	Number of Jobs Doable by		Employment	Number of Jobs Doable by		Employment	Number of Jobs Doable by	
		Level I	Level II		Level I	Level II		Level I	Level II		Level I	Level II
		20%	55%		10%	45%		15%	40%		20%	35%
NY	1,620	324	891	830	83	374	5,250	788	2,100	4,610	922	1,614
NJ	830	166	457	160	16	72	2,910	437	1,164	1,560	312	546
PA	100	20	55	220	22	99	270	41	108	660	132	231
GA	270	54	149	--	--	--	880	132	352	710	142	249
NC	290	58	160	150	15	68	580	78	232	870	174	305
TN	310	62	171	--	--	--	980	147	392	270	54	95
IN	1,146	229	630	1,455	146	655	3,906	586	1,562	3,289	658	1,151
IL	2,140	428	1,177	2,073	207	933	5,154	773	2,062	4,244	849	1,485
MI	650	130	358	1,940	194	873	2,820	423	1,128	7,570	1,514	2,650
OH												
WI	770	154	424	510	51	230	2,935	440	1,174	2,090	418	732
TX	150	30	83	70	7	32	360	54	144	800	160	280
MO	470	94	259	160	16	72	1,390	209	556	970	194	340
CA	2,020	404	1,110	523	52	235	5,622	844	2,249	7,905	1,581	2,768
13 State Total	10,766	2,153	5,921	8,091	809	3,641	33,057	4,959	13,223	35,548	7,110	12,442
U.S. Total Metal-Working	27,350	5,470	15,024	14,770	1,477	6,647	55,430	8,315	22,172	77,360	15,472	27,076

[1]State employment figures taken from Occupational Employment Statistics, 1977, for SIC 34-37.

[2]Estimates of percentage of operative tasks which could be done by Level I and Level II robots are taken from survey results. Percentage estimate used here is the average weighted response. Estimates are rounded to nearest multiple of five.

PRIME OPERATIVE TASKS FOR LEVEL II ROBOTS
(continued)

	Inspection			Assembly			Totals		
	Employment	Number of Jobs Doable by		Employment	Number of Jobs Doable by		Employment in 6 Categories	Number of Jobs Doable by	
State		Level I	Level II		Level I	Level II		Level I	Level II
		15%	35%		10%	30%			
NY	8,680	1,302	3,038	64,620	6,462	19,386	85,610	9,880	27,402
NJ	4,900	735	1,715	31,770	3,177	9,531	42,130	4,842	13,485
PA	940	141	329	2,250	225	675	4,440	581	1,497
GA	2,020	303	707	17,680	1,768	5,304	21,560	2,399	6,760
NC	2,820	423	987	26,160	2,616	7,848	30,870	3,373	9,599
TN	4,170	626	1,460	19,700	1,970	5,910	25,430	2,859	8,027
IN	9,307	1,396	3,257	65,641	6,564	19,692	84,744	9,579	26,948
IL	16,759	2,514	5,866	70,009	7,001	21,003	100,379	11,722	32,526
MI	29,100	4,365	10,185	98,670	9,867	29,601	104,750	16,493	44,794
OH									
WI	5,780	867	2,023	37,280	3,728	11,184	49,365	5,658	15,766
TX	2,580	387	903	12,560	1,256	3,768	16,520	1,894	5,209
MO	5,810	872	2,034	29,760	2,976	8,928	38,560	4,360	12,188
CA	20,429	3,064	7,150	112,250	11,225	33,675	148,749	17,170	47,137
13 State Total	113,295	16,994	39,653	588,350	58,835	176,505	769,107	90,860	251,385
U.S. Total Metal-Working	228,580	34,287	80,003	1,178,520	117,852	353,566	1,582,010	182,873	504,506

PRIME OPERATIVE TASK FOR LEVEL I AND LEVEL II ROBOTS

State	Employment in 3 Categories	Number of Jobs[1] Doable by		Employment in 6 Categories	Number of Jobs[2] Doable by		Employment in 9 Categories	Number of Jobs[3] Doable by[3]	
		Level I	Level II		Level I	Level II		Level I	Level II
NY	62,680	13,997	31,859	85,610	9,880	27,402	148,290	23,878	59,261
NJ	33,590	7,372	17,046	42,130	4,842	13,485	75,720	12,215	30,531
PA	12,240	2,687	6,168	4,440	581	1,497	16,680	3,268	7,665
GA	17,560	4,113	8,977	21,560	2,399	6,760	39,120	6,512	15,737
NC	20,910	4,633	10,602	30,870	3,373	9,599	51,780	8,006	20,201
TN	11,120	2,568	5,704	25,430	2,859	8,027	36,550	5,427	13,731
IN	61,078	13,515	30,982	84,744	9,579	26,948	145,822	23,094	57,930
IL	99,261	22,133	50,387	100,379	11,722	32,526	199,640	33,905	82,912
MI	144,100	32,023	73,072	104,750	16,493	44,794	284,850	48,516	117,866
OH									
WI	56,490	12,806	28,645	49,365	5,658	15,766	105,855	18,464	44,411
TX	16,620	3,951	8,508	16,520	1,894	5,209	33,140	5,845	13,717
MO	20,910	4,993	10,728	38,560	4,360	12,188	59,470	9,353	22,916
CA	95,188	21,854	48,595	148,749	17,170	47,187	243,937	39,024	95,782
13 State Total	651,747	146,645	331,273	789,107	90,860	251,385	1,440,854	237,507	562,660
U.S. Total Metal Working	1,165,630	262,261	573,972	1,582,010	182,873	504,506	2,747,640	445,134	1,098,478

[1]Occupations include: production painters, welders, flamecutters, machinists, machine tool operators (combination and numerical control and tool room), drill press, grinding, abrading, lathe/turning, milling/planing, punch press.

[2]Occupation includes: electroplaters, heat treaters, buffers, packagers, filers/grinders/buffers, inspectors, assemblers.

[3]Sum of other two sets of figures

Table 5-26: SUMMARY OF PRIME OPERATIVE TASK

Table 5-27: ESTIMATES OF THE NUMBER OF JOBS ROBOTS COULD DO IN ALL MANUFACTURING

Occupation	Total Employed, 1979[1] All Manufacturing	% of Jobs Which Could be Done by:[2] Level I	Level II	Number of Jobs Which Could be Done by: Level I	Level II
Assemblers	1,289,000	10%	30%	128,900	386,700
Checkers, Examiners[3] and Inspectors	746,000	15%	35%	111,900	261,100
Packers and Wrappers (Except meat and produce)	626,000	15%	40%	93,900	250,400
Production Painters	185,000	45%	65%	83,250	120,250
Welders and Flame-cutters	713,000	25%	50%	178,250	356,600
Machinests und Machine Operators[4]	3,027,000	20%	50%	605,400	1,513,500
	6 586,000[(5)]			1,201,600	2,888,450

[1]Employment Figures from Statistical Abstract, 1980, Table 697, Persons Employed by Sex, Race, and Occupation, 1972 and 1979.

[2]The percentage of jobs which could be done by Level I and Level II robots are based on survey results within the metalworking sector. Percentage estimates are the average weighted responses of survey results, rounded to nearest multiple of 5.

[3]Includes testers and inspectors. Since there are more than four times as many testers as inspectors in metalworking, the percentage estimate for inspectors are used.

[4]Includes the following occupational categories: machinists and jobsetters, precision machine operators, machine operators, and punch press operators.

[5]The difference between this figures and the estimate of the number of operatives given in the table "Estimates of Percent Coverage in Metalworking for Selected Occupations" is as follows:

6,586,000	-	642,000	+	780,000	+	263,000	=	6,987,000
(total given above)	-	(machinest and jobsetters)	+	(freight and material handlers)	+	(cutting operatives, nec)	=	(total operatives and unskilled workers)

6. SHORT TERM TRANSITIONAL ISSUES

6.1 INTRODUCTION

This chapter will study some of the relationships between the introduction of robotics and effects on the work force. Although we cannot account for the effects on individuals, we can discuss the aggregate aspects of the transition. Some of the workers who are displaced will be retrained or transferred to other jobs within the firm, others will be scheduled for early retirement, and still others will be laid-off due to job eliminations and decreased manpower requirements. The nature of the transition to robotics will depend on a variety of factors, including the magnitude of worker displacement, the ages of the workers, the ability of the economy to reabsorb workers, the rate of introduction of robots,and the mechanisms which will guide the transition.

We have developed a simple model to aid our understanding of the effects of the introduction of robotics. This exercise helps to conceptualize the first order implications of new technology on the labor force by identifying the critical components which influence worker displacement.

The actual decision to adopt new technology rests with the individual firm. The real changes will occur at the plant level; as such, the plant is an appropriate level of analysis. This analysis will concentrate on the changes which take place *after* robots are installed into the plant. Given the difficulty of focusing on the specific case of an individual firm, we concentrate on the general case and discuss the global issues here.[41] The model allows analysis at different levels of aggregation by varying the input numbers. For example, statewide analysis is useful since states administrate the welfare and unemployment compensation programs.

6.2 A DESCRIPTION OF A MODEL OF LABOR FORCE CHANGE

A static analysis at any level (firm,industry or state) begins with a worker population as a given number at any specific time. This represents a stock of labor which can be described by specific demographic and labor force characteristics. Of course, the labor force is not static,but is changing over time. The worker population will change due several factors which occur independently of the introduction of a new technology.These include:

- Natural Attrition

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[41] See page 187 for a hypothetical example at the plant level.

- regular retirements
- deaths/disabilities
- Firings/Voluntary terminations.

- Accessions
  - Replacements
  - New positions

The number of workers at any future time is determined by the beginning number of workers, the number of workers leaving the job (natural attrition) and the number of new workers joining the work force (accession). In this way, the work force can be conceptualized as a flow of individuals: the rate of flow being determined by the number of individuals entering and leaving the work force.

6.2.1 DYNAMIC ELEMENTS

The introduction of a new technology sometimes alters the flow of workers within a labor market. A greater dependency on capital changes the capital/labor mix, sometimes resulting in an excess of certain types of labor. The amount of the labor surplus will depend on a series of dynamic elements. Consider, for example:

- the natural attrition rate of the industry;
- the number of workers replaced for each new machine installed;
- the rate of the introduction of the new technology;
- the prevailing economic conditions;

Natural attrition, the spontaneous change in the work force, represents a way to minimize worker displacement. If the technology is introduced at a level roughly equivalent to the natural attrition rate, less worker displacement will occur. Over a short time period enough workers will leave the industry so that those wishing to remain will be secure in their employment.

The replacement rate refers to the number of workers displaced for each robot introduced. Replacement ratios will be variable for different job classes and for specific job tasks. On the individual factory level, a seemingly small variation in the replacement ratio (for example, 1:4 instead of 1:3) can have a substantial impact on a worker population.

The rate at which new technology is introduced obviously affects the outcome for workers. Management can choose to change an entire production line or one operation at a time. If the rate of introduction of the new technology is low, the short term impact on the work force will be lessened , all others things being held constant.[42] If new technology is introduced at a rapid rate, more workers will be displaced. This could result in a number of workers with similar skills entering the job market at the same time.

The prevailing economic conditions at the time of introduction characterizes the environment that receives the displaced workers. If the industry is expanding or markets are growing rapidly, it is more likely that displaced workers can be reabsorbed. If the displacement takes place in a geographic area which has a shrinking economic base, the effects could place additional burdens

6.2.2 Possible Outcomes for the Labor Force

The end result of the introduction of the new technology is a redistribution of the original stock of workers among the following possible alternatives:

- retirement:
  - normal retirement: for those of the proper age and qualifications;
  - voluntary early retirement: for those who meet certain age and service qualifications, but do not fall under the coverage of normal retirement;
  - special early retirement: for those who are given the choice to leave the work force earlier than normal without benefit penalty.
- Retention:
  - transfer horizontally: workers who are laid off,either temporarily or permanently;
  - transferred vertically: workers who are moved to other jobs/departments within the plant;
  - retraining: a subset of those transferred horizontally who will have to be retrained to learn how to operate new machinery.
- voluntary quitting: Some workers may elect to find other employment if the are disgruntled with the changes on the job;
- lay offs: Lay offs can be permanent or temporary. If permanent, workers have no recourse or guarantee of future employment. Temporary lay offs provide workers the option to be rehired on the basis of seniority, skill-level, and job class.

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[42] A low introduction rate may jeopardize the firm's competitive position, and indirectly lead to lay offs too, but this type of trade off will not be discussed here.

6.3 THE ROLE OF UNIONS

One of the major mechanisms which affect worker assignments to the range of alternatives are union contracts. Over 90% of the workers in the metalworking sector (SIC 34-37) are covered by some sort of union collective bargaining agreement. We can expect that unions and union membership will be heavily involved in the mechanics of the transition to robotics. Although no information exists which cross classifies workers by SIC code and specific union membership, it appears that the main unions organized in the metalworking industries are:[43]

- United Automobile, Aerospace and Agricultural Implement Workers of America (UAW)
- The International Brotherhood of Electrical Workers (IBEW)
- The International Association of Machinists and Aerospace Workers (IAM)
- The International Union of Electrical, Radio and Machine Workers (IUE)

Table 6-1: EXTENT OF UNIONIZATION IN SIC 34 - 37

SIC #	TOTAL IN BARGAINING UNITS	TOTAL UNION MEMBERS IN UNITS	PERCENT UNIONIZED IN BARGAINING UNITS
34	606	559	92.24
35	734	696	94.82
36	694	645	92.94
37	1219	1154	94.67

--numbers are in thousands

SOURCE: BLS 1974

The goal of management is to maximize output per dollar spent on input input being some combination of labor and capital. In reality, management also simultaneously attempts to maximize a whole series of indicators, including the value of the firm's stock, cash flow, return on equity (profit) liquidity, and market share and growth relative to other firms in the market. The welfare of employees is considered too, but primarily insofar as it contributes to the other goals of the firm. In contrast to the goals of management, unions put their highest priority on worker satisfaction, job security and their own survival. Unions have

[43] This list does not include all the unions in these industries.

seldom opposed the introduction of new technology as long as the benefits brought about by this technology are shared with their members. Through negotiations with management, unions have been able to increase wages and fringe benefits, improve working conditions, and insulate workers against lay-offs and other cutbacks.

Collective bargaining contracts are the formal mechanism that unions use to affect company policy. Through contract negotiations unions are able to influence company policies as well as their own job security and compensation rates. Union contracts are marked by their large number and the diversity of their provisions and sphere of influence. A comprehensive review of union contracts was beyond the constraints of this project. We have reviewed representative contracts sent to us by the four unions previously identified. We looked for clauses which would affect the introduction of new technology.

Three of the four unions listed above have provisions which set up joint union-management committees to discuss the phasing in of new technology. These committees receive advance notice of impending technological changes and, when necessary, negotiate possible policies to mitigate the negative effects within the collective bargaining unit. These policies include advanced notification to workers, agreements to minimize displacement and provisions for retraining . These options provide a flexible mechanism to deal with the specifics of most new situations. The IBEW contract is an exception to the other three. It specifies that the company will retain the right to introduce technology without the consultation of the union. The importance of giving workers advance notice of the arrival of new technologies is discussed on page 58.

The union contracts include clauses relating to job security, job integrity in the workplace and benefits to the workers in the event of a lay-off. Job security attempts to provide workers with guarantees of continued employment at agreed upon wage and benefit levels while job integrity deals with the maintenance of the bargaining unit in the face of changes in the production process. Such clauses encompass concerns relevant to the actual working conditions in the firm. In the event that job security is not attainable, the union attempts to ease the situation of the individual worker in the period after displacement.

The emphasis likely to be placed on securing retirement benefits depends on the age distributions of the workforce. If a large proportion of workers are near retirement age, more emphasis will be placed on securing retirement benefits.[44] Specially negotiated early retirement plans may allow older workers and those with a pre-specified number of accumulated work years to retire a little earlier, leaving the remaining jobs open to younger workers.

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[44] See page 201 for a discussion of the importance of age distributions.

Seniority is a job security issue and of interest to the unions. Senority can be plant or department wide. Plant-wide seniority specifies that the most senior employees retain their jobs within the plant during periods of lay off. This strategy makes it possible for a senior employee to be moved to a job he is less qualified for or over qualified than was the person who was laid off. Department-wide seniority means that workers have seniority only in their own department. If the whole department is eliminated, a worker will be laid off no matter how much seniority he has. Plant-wide seniority gives the most security to employees in the face of lay offs due to the introduction of new technology.

6.3.1 Relevant Contract Clauses

Figure 6-1 summarizes several contract clauses relevant to the introduction of new technology identified from the four union contracts we surveyed. These clauses are:

- Paid Personal Holidays (PPH): increases wages while decreasing work time by giving workers more days off with pay (in addition to standard holidays). For example, the UAW has negotiated twenty-six Paid Personal Holidays for each member over a three year period. In the event of possible worker displacement, reduced work time redistributes the available jobs to a greater number of workers. The intent is to reduce the number of workers laid off. Other unions have implemented similar plans by increasing the standard vacation time. These policies may reduce potential loss to union of membership. On the other hand, they definitely increase the firm's labor costs without increasing input, thereby reducing productivity.

- Supplemental Unemployment Benefits: used in addition to unemployment compensation to aid workers through lay off periods. Nationally, the UAW is the principal advocate of this program.

- Transition Allowances: provided to workers when the firm transfers employees from plant-to-plant. These allowances range from $500 to $1760 in the contracts we looked at. In some cases benefits will also follow the employee from plant-to-plant. Seniority does not transfer for the IAM.

- Advance notice of technological change: required in all four of the reviewed contracts. The extent of union input into such a change varied from union to union. The UAW and the IAM have committees consisting of both union and management representation which would study and discuss each change in technology, whereas, the IBEW contract indicates that the company retains the sole right of deciding the introduction of new technology.

- Severance Pay: used to provide for workers who are permanently laid-off. It effectively pays workers to leave their jobs. Severance Pay is often used in cases of special retirement,where workers are paid lump sums to leave the job and in addition, receive a percentage of their original pension benefits. This plan has the advantage of easing pressures on the union pension fund. It also provides the firm with a quick,but very costly means of reducing the size of the workforce.

- Retraining Provisions

- Three of the four unions studied have negotiated retraining provisions as the responsibility of the employer. By accepting the cost burden, the employer has shown an interest in allowing the employee's skills to improve along with technology. The IUE has stated that it will make available specialized training for qualified workers displaced by new technology. Such a provision would make it possible for some displaced workers to be trained in the supervision or maintenance of robots which had originally replaced them. However not all displaced workers can be reabsorbed in this way.

- Sharing of Increased Productivity Benefits: are the result of improved technology providing increased productivity and in turn increased corporate profits. By sharing the increased profits with the union, the company improves the acceptance of new technology in the work place. The UAW's Wage Improvement Factor was the only example of shared increased productivity benefits found in the contracts studied.

6.4 CHANGES TO THE UNION AND THE WORK FORCE

The viability of options to deal with potential displacement caused by the introduction of new technology depend, in part, on the following factors:

- Age structure of the worker population;

- New Job skill requirements;

An examination of work force age distribution aids the union and management in making decisions regarding feasible forms of retirement. It also suggests possible collective bargaining strategies, and suggests whether increased employer contribution to pension funds is a better than increased contribution for Supplemental Unemployment Benefits (SUB). If there is a greater proportion of younger workers in a plant, natural attrition and retirement options may seem less appropriate than retraining, relocation allowances, rehiring(transferring), and severance pay. If there is a large proportion of older workers, unions may emphasize natural attrition and retirement benefits.

New technology has the potential to change job skill requirements. For example, a worker who previously worked as a welder on an assembly line may be used to supervise and maintain a robot welder. Such a robot may be used to replace two or more workers, thereby increasing the relative responsibility of the robot supervisor/operator. The worker's responsibilities and job description undergo significant changes. A certain degree of retraining may be necessary. The reconciliation of the worker's skill and the new skill requirements is covered in Chapter 7.

Characteristics of Clauses Relevant to the Introduction of New Technology

	UAW	IAM	IUE	IBEW
Retraining provisions, cost burden on employer	new position retraining determined by a committee of management and union representatives	company responsible for establishing retraining programs at its own expense and during regular work hours	company will make available specialized training for qualified workers displaced by technology	
Paid personal holiday	workers become eligible for PPH after one year of seniority and a set number of pay periods per year			
Relocation allowances	amount of allowance ranges from $500 to $1760 depending on workers marital status and transfer distance. Seniority and other benefits unaffected	company provides moving arrangements and pays transfer costs: transferred employees carry all rights except seniority to new plant: seniority at new plant starts on first day		
Advance notice	advance notice provided through a National Committee on Technological Progress comprised of union and management representatives	a joint union-management Committee for Technological Change will study effects of technological change on workers	a joint union-management committee will discuss impact of technological change on workers	company retains sole right to manage its business including right to introduce technological improvements
Sharing of increased productivity benefits (wage improvement factor)	exclusive of cost-of-living, management profits from new technology are shared with the UAW			
Supplemental unemployment benefits	set to aid laid off auto workers			employees receive a retirement service, if eligible, or a termination allowance
Severance pay				employees eligible after five years of service: these employees will retain all rights and privileges

Source: Compiled from Collective Bargaining Agreement Between General Motors Corporation and the UAW 1979; Columbia Lighting Co. and IBEW Local 73, 1979-1982; General Motors and IUE 1979; and the IAM Model Contract.

Figure 6-1: UNION CONTRACT CLAUSES RELEVENT TO THE INTRODUCTION OF NEW TECHNOLOGY

6.5 THE UNION OPTIONS

Natural attrition describes the reduction in the work force due to worker-initiated job termination, and firing unrelated to new technology,worker death, and disability or illness. Rates of natural attrition vary from plant to plant, and will depend on the age distribution of workers within the plant, longevity of the plant or industry in the area, and type of work. A union's strategy in regards to worker protection will differ depending on the rate of natural attrition in a particular plant. If the rate is high, the work force might be allowed to decrease naturally by restricting the number of new hires until some equilibrium is reached. If the natural attrition rate is low, unions seek other ways of protecting their members.

The rate of growth of the industry will also determine the effect on the work force and appropriate union response to new technology. If the rate is static, unions might look to natural attrition rates within the plant and the proposed rate of introduction of new technology to determine their strategies. If the rate is increasing, there will probably be more jobs created, thereby increasing the possibilities of relocation of displaced workers to new departments or plants and retraining workers for newly created jobs. If the rate is decreasing, strategies might include retraining and moving allowances.

In the process of displacement, certain workers will be needed for maintenance and supervision of robots. One of the union's policies might be to keep these jobs in the collective bargaining unit so that the union's power base will be preserved. The integrity of the bargining unit is maintained if the people who supervise robots remain a part of the union. A major change could occur if unions are not able to keep robot supervisors and maintenance personnel within the bargaining unit. The effectiveness of a strike would be lessened if management could continue to produce through the use of robots supervised by white-collar employees. A union's power stems from its ability to organize workers in key operations. When existing or newly created key operations are taken out of the bargaining unit, unions will lose some of their bargaining power. There are already indications that unions will attempt to increase their membership by attracting new professions to their ranks.

Seniority rights, which are exercised during periods of lay offs, have the potential to create tensions between those remaining within the plant and those actually laid off, especially if those laid off are women and minorities. The Equal Employment Opportunity Commission has attempted to set guidelines with respect to which workers are laid off. In theory, the EEOC believes that race and sex should be more important then seniority in determining possible lay offs. In practice, the courts have stated that seniority is more important. By adhering to strict seniority rules, a firm runs the risk of alienating women and

minorities; or by adhering to EEOC guidelines, a firm might have to violate contractual seniority rules.

6.6 CONCLUSIONS

Both unions and management have a difficult task: to protect affected workers in the short run without raising production costs enough to jeopardize the existence of the plant in the long run. Each side must take into account the other's needs and constraints. Management must be aware of the social and personal costs to workers faced with unemployment. Unions must be aware of the effect of the wide use of high-cost benefits on the firm's cost function.

There exists a series of possible events which could seriously affect both unions and management. These events could occur as follows:

1. American industries face increasing competition from foreign markets. Because of this competition, industry is forced to continually modernize its production process. One important aspect of modernization is robotics.

2. As industry improves its production process, workers will be displaced in the short run. Such worker displacement involves a large cost to both the displaced workers as well as to society as a whole. The trauma and financial problems associated with being laid-off are clearly evident to the unemployed worker. Society also pays a cost through factors such as increased unemployment compensation payments and a shrinking work force.

3. Unions will then attempt to provide for the displaced workers. They will achieve this through concepts such as Paid Personal Holidays, Special Early Retirement, and Relocation Allowances.

4. As the cost of labor is increased, capital expenditures become more financially attractive. When the increased cost of labor is combined with the industry's need to compete abroad, the firm has no choice but to increase the amount of capital used. In effect the unions might price themselves out of the market.

Industry will suffer if they are unable to modernize. Unless they do so, some firms face a realistic threat of losing their markets to other (often foreign) producers who have already upgraded their facilities with robotics or with other types of computer controlled production technologies. Unions, and individual workers will also suffe. if firms fail, because union members will lose jobs. We might face a dilemma where the unions are faced with either losing some jobs due to robotics or all the jobs as a result of firm failure. However,

We have three recommendations for avoiding the above scenario.

1. Joint union-management committees should be formed. These committees

would provide advance notice to the union leadership of an impending technological change. With this knowledge unions will be in a better position to adequately provide a smoother transition to the presence of improved technology.

2. When providing for potentially displaced workers the age distribution of the affected worker population should be considered. The age distribution can dictate the proper alternative for the method used to provide for the displaced workers. For example, if worker age distribution is skewed toward the regular retirement age, early retirement becomes the best solution. However, if the age distribution is skewed noticeably younger, then other alternatives such as retraining or severance pay need to be considered.

3. Some methods of providing for the displaced workers entail a high cost while others entail a low cost to the firm. A high cost method would be one that increased wages while simultaneously decreasing work time. Examples of high cost methods include Paid Personal Holidays, increased vacation time, and in some cases Special Early Retirement. A low cost method would include provisions such as retraining or in most cases severance pay. Unions should be willing to accept and utilize the lower cost methods in providing for its displaced workers.

The Technology Initiated Change Model, beginning on page 187 offers a framework for individual firms to predict how many workers would be displaced if robots were introduced. Individual firms, as well as some unions, will likely have data on the age distribution of the workforce, and attrition rates. The number of workers that would be replaced by each robot introduced depends on the application, and on the specifics of the production process. This number can be estimated. The "control" variable is the number of robots introduced. After the firm , or union, has filled in the information on attrition rates, and replacement rates, they can analyze how many workers would be displaced for a given number of robots introduced. By doing this, differing amounts of worker displacement can be studied. Once the amount of worker displacement is estimated, alternative policies for accommodating the displaced workers can be proposed.

In the past, labor and management relationships have typically been adversary in nature. Given the current economic situation of American manufacturing industry, this adversary relationship is giving way to a more cooperative one. We believe that if the transition to robotics is to occur smoothly, this cooperation *must* continue.

7. HUMAN RESOURCE POLICIES

7.1 INTRODUCTION

As technology becomes more advanced and manual skills are embodied in programmable machines, there may be a major shift in the demand for labor skills needed in the economy. As a result, potential workers should be equipped with skills which qualify them for jobs which will not be within the capabilities of robots, and potentially displaced employees should obtain marketable skills. The responsibility for training and retraining efforts can span the spectrum, including the public sector, private sector, and the individual. It is this total preparatory effort which will determine the extent of disruption which may occur during the introduction of robotics into the workplace as well as the distribution of the potential burden of adjustment.

The purpose of this chapter is to provide an understanding of the role of each sector of the economy in preparing the workforce for the robotic era. First the role of retraining in the economy is examined, followed by an inventory of existing training and retraining programs. We then evaluate the current programs in light of the robotic scenario. In conclusion, recommendations for the future development of human resource policies which will ease the transition into the robotic era are offered.

7.2 THE ROLE OF RETRAINING IN THE ECONOMY

Retraining is important from both the viewpoint of the employee and the employer. The employee views retraining as any training which takes place after his basic education and his first job training is completed. It is often a means to secure continued employment. Employers view retraining as a necessary means of upgrading labor productivity when new and advanced technology is adopted within the organization.

There are several methods of retraining currently being used. The major types are are on-the-job, classroom, and institutional training. Continuing education is becoming more popular as a retraining mechanism. This is primarily based on the premise that a "modern technological society may demand training and education throughout most people's working lives (QWL 77b)." Vocational education is another mechanism which has been used to generate the needed training and education to adapt to advanced technology. All of these methods are be more fully described later in this chapter.

It is difficult to measure the extent of existing retraining programs because "most private (and public) employers do not tally training expenditures in consistent and measurable ways." Additionally, quantitative measurements are difficult because programs are usually conducted

informally and each situation is unique. The nature of the production process, types of occupations, and the rate at which advanced technology is introduced is more or less unique to every firm. No statistics, therefore, exist on the number of people in training programs.

There have been attempts to quantify the amount of retraining that goes on by computing the number of employees who have received some form of retraining due to clauses contained in their union contracts. This is difficult, however, because some unions only have informal, verbal agreements about retraining provisions (QWL 77b).

7.3 RETRAINING IN INDUSTRY

7.3.1 General Policies

Firms do a great deal of retraining, but they are not equipped to deal with the numbers and types of retraining which may be caused by the introduction of robotics into the workplace. Firms usually retrain as new positions become available. Retraining, for some jobs, is tied to the bidding and seniority systems. The bidding system is such that when a position becomes available (either through promotion or attrition), the job is posted around the company, and employees may "bid" for the position by formally applying. People are chosen for the position on the basis of several criteria: seniority, experience in that field or performance in an interview. Having received the position, the employee is trained for it. Most large firms hire on an introductory level and allow their employees to rise within the firm by alternately training and promoting.

Retraining also takes place as a result of downward mobility. In most firms displaced employees have "bumping" rights, in which they can displace employees with less seniority, thereby creating a chain of "bumpers" and "bumpees", eventually eliminating the person with least seniority in the department. The rules vary depending on the firm as to whether the "bumper" must already have experience in the department being bumped into, must stay within the confines of a certain department, or has the freedom to be newly trained in a brand new position.

It is often asserted by companies currently using robots in their factories that no positions have been eliminated by robots. General Electric Company, among others, has taken precautions to insure that employees displaced by robotics are not laid off. Instead, these employees have been retrained and transferred to other jobs. Actual decreases in employment have been caused only through the attrition process. (Greene 80) Similarly, when ALCOA introduced a robot into their passenger car wheel presses, the affected workers were retrained for the wheel alignment and inspection sections.

If industries are not expanding, however, positions may be eliminated through the attrition process. As employees leave the industries for reasons such as retirement, transfers and disability, their positions may not be filled. This leads to an absolute shrinkage in the workforce.

There is a segment of the labor force whose skills are no longer needed. This includes people who have been trained but never hired, as well as unskilled entry-level employees who have been displaced. Industry retrains experienced employees to move laterally within the firm, but is not equipped or financially motivated to handle the "structurally" unemployed segment of the workforce. Thus, although industry is assuming some of the responsibility for dealing with worker retraining, it cannot be held responsible for dealing with the entire problem of unemployability, especially where basic educational background is inadequate.

Firms employ several methods of retraining employees. The most common is "on-the-job" (OTJ) with a supervisor watching. A more formal approach sometimes called "vestibule training", is a combination of classroom and hands-on training. The advantage of both of these methods is that the employee gains familiarity with machines that he will actually be using. The disadvantage is the expense involved, both in terms of teacher and machine. Production-type are not designed for teaching; using these machines for teaching reduces production and therefore revenues. A second formal retraining approach is that of utilizing an already existing training center (i.e. vocational school, trade school, community college, etc.). Although this is also costly and the employee may still need additional training with the machinery at the workplace, a proper school may teach more efficiently. Moreover, workers may be taught prior to employment.

7.3.2 Non-Profit Training Institutions

Examples of such institutions exist on both the national and local levels. Bidwell Corporation of Pittsburgh presently offers training programs in construction, carpentry, bricklaying and plumbing. Firms such as U.S. Steel, Westinghouse and Warner Communications contract with Bid-well when it is more convenient and cost-effective than training for the needed skills in-house.

Founded in 1964, the Opportunities Industrialization Center (OIC), Inc., a non-profit organization, has opened career paths to unskilled and disadvantaged individuals. In New York City, for example, OIC provides a free Comprehensive Manpower Training Program with classroom instruction in a wide range of occupational and vocational areas in communities where the need for a relevant training program is evident. In eleven years of operations, OIC/NYC alone has trained and placed over 16,000 people. Today there are on

hundred forty OIC affiliates in 41 states. OIC, Bid-well, and similar institutions have the potential to play an effective role in meeting the labor needs of a more highly automated society.

As previously discussed, firms initiate retraining most frequently "on demand", i.e. after a need is recognized. However, a certain amount of retraining is done voluntarily by the employee at a cost to both the company and the individual. This type of training varies depending upon the amount of money the company is willing to invest, and the types of training the employee is permitted to explore. Many companies will compensate only for courses which they feel will benefit the employee by making him more efficient in the position he presently holds, while others allow the employee to prepare for transfers within the firm. Still others only permit employees to study within their respective job classification. Another alternative is a "general" education system which provides employees with information about other jobs within the company. One example is the Welding Tube Division at Jones and Laughlin Steel, which makes accessible to employees instructions on machine operation. This allows an energetic employee to prepare himself in the event that a position becomes available.

These volunteer methods of retraining could be effective in preparing the workforce for robotization. In this context, advance notice is helpful. Given enough lead time and the opportunity to train in alternative areas, employees may be able to advance within the company or transfer to other companies. The question of who should bear the costs for this retraining--the public sector, private sector (industry), or the individual--is one which has been much disputed. The most likely answer is a combination of all three.

Provisions for displaced employees who are not covered by industries' training and retraining policies are available. They are in the form of both monetary assistance and public sector training.

7.3.3 Monetary Assistance

Currently there are two forms of monetary assistance. The first is Unemployment Compensation (UC)--an insurance system which is paid into by the former employer during the time of employment. (Penn DOL ??) The second is the Trade Adjustment Assistance (TAA). Workers who lose their jobs due to import competition are eligible for this assistance. (trade) This program has come under attack recently, because some feel that the cause of the layoff, since it is beyond the control of the employee, should not influence the amount of assistance they receive.

There are several deficiencies in existing monetary assistance programs. Intrinsic to these

programs is a disincentive to find employment or explore training alternatives. For example, recipients of Unemployment Compensation in Pennsylvania can only earn forty percent of their weekly claim from outside sources. After that the additional is deducted dollar for dollar from the weekly UC check. There are severe limitations on the amount of training which recipients may pursue without jeopardizing benefits. Also, claimants can easily receive benefits for an extended period without exploring job opportunities, for they are rarely sent on interviews or questioned about their job searching attempts. In addition, placement efforts on the part of the states are extremely lacking.

Although these programs can not be considered long-term solutions, they can be improved in two ways. First, they can be modified to foster growth of marketable skills among the unemployed by allowing these people to retrain while still receiving current benefits. Secondly, they can be modified to include a job placement function matching available skills with the demand for those skills. This is attempted currently, but in a very unsystematic and haphazard manner. By providing these additional features, in addition to the essential financial assistance, they can ease the transitions of the economy.

7.4 COMPREHENSIVE EMPLOYMENT AND TRAINING ACT--CETA

7.4.1 Goals and Programs

The public sector has some programs which train and retrain parts of the potential workforce which the private sector fails. The two primary public sponsored training and retraining facilities are set up through the Comprehensive Employment and Training Act (CETA) and vocational training. These programs, or similar ones, could play a large role in easing the transition into a workforce including robots. Following is a description of current CETA programs.

CETA's major objective is "to provide training and improve employment opportunities for the economically disadvantaged and for the unemployed and underemployed. The strategic objective is to place the administration of manpower programs with local authorities and permit them to select programs appropriate to their needs." (NAS 78)

CETA consists of eight program titles, designed to meet the needs of targeted groups described by the federal government as economically disadvantaged, unemployed, or underemployed. Each title is discussed in detail in in the act below.

TITLE I, ADMINISTRATIVE PROVISIONS, CONTAINS THE GENERAL PROVISIONS GOVERNING THE ACT, INCLUDING THE DESIGNATION OF STATE AND LOCAL PRIME SPONSORS TO

ADMINISTER THE PROGRAM, THE PLANNING AND PLAN APPROVAL PROCESS, AND SPECIAL RESPONSIBILITIES OF THE GOVERNOR AND STATE AND LOCAL ADVISORY COUNCILS. THE TITLE ALSO ESTABLISHES AN OFFICE OF MANAGEMENT AND CONTAINS STRENGTHENED PROVISIONS RELATING TO PROGRAM AUDITS AND INVESTIGATION AND COMPLIANCE ACTIVITIES. IN ADDITION, IT CONTAINS TIME LIMITATIONS FOR PARTICIPATION IN PROGRAMS AUTHORIZED BY THE ACT, AS WELL AS NEW PROVISIONS FOR PUBLIC SERVICE EMPLOYMENT WAGES.

TITLE II, COMPREHENSIVE EMPLOYMENT AND TRAINING SERVICES, COMBINES THE COMPREHENSIVE MANPOWER SERVICES PREVIOUSLY AUTHORIZED UNDER TITLE I AND THE PUBLIC EMPLOYMENT PROGRAMS PREVIOUSLY AUTHORIZED UNDER TITLE II. ALLOWABLE PROGRAM ACTIVITIES INCLUDE TRAINING, WORK EXPERIENCE, UPGRADING, RETRAINING, EDUCATION, AND OTHER SERVICES (PARTS A,B, AND C) AND COUNTERSTRUCTURAL PUBLIC SERVICE EMPLOYMENT (PART D) NEEDED TO ENABLE PARTICIPANTS TO OBTAIN UNSUBSIDIZED EMPLOYMENT. PARTICIPANTS ENROLLED IN TRAINING PROGRAMS AND SERVICES (EXCEPT UPGRADING AND RETRAINING) MUST BE ECONOMICALLY DISADVANTAGED AND EITHER UNEMPLOYED, UNDER EMPLOYED, OR IN SCHOOL. PARTICIPANTS IN PUBLIC SERVICE EMPLOYMENT MUST BE ON WELFARE OR ECONOMICALLY DISADVANTAGED AND UNEMPLOYED 15 OR MORE WEEKS.

TITLE III, SPECIAL FEDERAL RESPONSIBILITIES, AUTHORIZES THE SECRETARY OF LABOR TO PROVIDE SERVICES TO SEGMENTS OF THE POPULATION WHICH EXPERIENCE PARTICULAR DISADVANTAGES IN THE LABOR MARKET. ADDED TO THE ORIGINAL LIST OF PERSONS WITH SUCH DISADVANTAGES ARE WOMEN, SINGLE PARENTS DISPLACED HOMEMAKERS, INDIVIDUALS WHO LACK EDUCATIONAL CREDENTIALS, AND PUBLIC ASSISTANCE RECIPIENTS. THE TITLE CONTINUES AUTHORIZATION OF PROGRAMS OF RESEARCH, TRAINING AND TECHNICAL ASSISTANCE, EVALUATION, LABOR MARKET INFORMATION, AND COMPUTERIZED JOB PLACEMENT. IN ADDITION, IT AUTHORIZES WELFARE DEMONSTRATION PROJECTS FOR MIDDLE-AGED AND OLDER WORKERS, AND A PROGRAM FOR THE COORDINATION AND PARTNERSHIP BETWEEN PRIME SPONSORS AND STATE EMPLOYMENT SECURITY AGENCIES. VOUCHER DEMONSTRATION PROJECTS ARE ALSO MANDATED.

TITLE IV, YOUTH PROGRAMS, PROVIDES FOR PARTICULAR YOUTH PROGRAMS, INCLUDING THOSE ENACTED IN THE YOUTH EMPLOYMENT AND DEMONSTRATION PROJECTS ACT OF 1977 (EXCEPT FOR THE YOUNG ADULT CONSERVATION CORPS. WHICH IS STILL IN TITLE VIII). JOB CORPS, AND THE SUMMER YOUTH PROGRAM.

TITLE V, NATIONAL COMMISSION OF EMPLOYMENT POLICY, RENAMES AND RECONSTITUTES THE NATIONAL COMMISSION FOR MANPOWER POLICY, WITH CABINET PARTICIPATION REDUCED AND INCREASED INDEPENDENCE FROM THE DEPARTMENT OF LABOR PROVIDED FOR.

TITLE VI, COUNTER CYCLICAL PUBLIC SERVICE EMPLOYMENT PROGRAM, PROVIDES FOR A COUNTER CYCLICAL PUBLIC SERVICE EMPLOYMENT PROGRAM, AUTHORIZING THE FUNDING OF SUFFICIENT JOBS TO EMPLOY 20 PERCENT OF THE NUMBER UNEMPLOYED IN EXCESS OF A 4-PERCENT RATE OF UNEMPLOYMENT. JOBS ARE AUTHORIZED FOR 25 PERCENT OF THE NUMBER OF UNEMPLOYED IN EXCESS OF A 4-PERCENT RATE OF UNEMPLOYMENT WHEN NATIONAL UNEMPLOYMENT IS 7 PERCENT OR HIGHER. FIFTY PERCENT OF THE FUNDS MAY BE USED ONLY FOR THE EMPLOYMENT OF PERSONS IN PROJECTS OF LIMITED DURATION, AND ALL PERSONS NOT WORKING IN PROJECTS MUST BE EMPLOYED AT ENTRY-LEVEL POSITIONS.

TITLE VII, PRIVATE SECTOR OPPORTUNITIES FOR THE ECONOMICALLY DISADVANTAGED, PROVIDES FOR A DEMONSTRATION PROGRAM TO TEST THE EFFECTIVENESS OF A VARIETY OF APPROACHES TO INCREASE THE INVOLVEMENT OF THE BUSINESS COMMUNITY IN EMPLOYMENT AND TRAINING ACTIVITIES SUPPORTED UNDER THE ACT AND TO INCREASE THE PRIVATE SECTOR EMPLOYMENT OPPORTUNITIES FOR ECONOMICALLY DISADVANTAGED PERSONS. THE

TITLE PROVIDES FUNDS TO PRIME SPONSORS FOR THE ESTABLISHMENT OF PRIVATE INDUSTRY COUNCILS, A MAJORITY OF WHOSE MEMBERS SHALL BE FROM THE BUSINESS COMMUNITY. THE COUNCILS WILL PARTICIPATE WITH THE PRIME SPONSOR IN THE DEVELOPMENT OF PRIVATE SECTOR OPPORTUNITIES FOR ECONOMICALLY DISADVANTAGED PERSONS.

TITLE VIII, YOUNG ADULT CONSERVATION CORPS, CONTAINS THE AUTHORIZATION FOR THIS PROGRAM, ENACTED BY THE YOUTH EMPLOYMENT AND DEMONSTRATION PROJECTS ACT OF 1977. THE CORPS PROVIDES UP TO 1 YEAR OF EMPLOYMENT FOR OUT-OF-SCHOOL, UNEMPLOYED YOUNG PEOPLE AGED 16 THROUGH 23 YEARS, WITH PREFERENCE GIVEN TO THOSE RESIDING IN AREAS OF SUBSTANTIAL UNEMPLOYMENT.

SOURCE: EMPLOYMENT AND TRAINING REPORT TO THE PRESIDENT: ETA, 1977.

The overall program objective of CETA is two-fold; structural and counter-cyclical. The structural objective, which was present in the original legislation, is to improve through remedial training, the employability of persons lacking knowledge and access to the working world, and to expand employment opportunities in areas of chronic and substantial unemployment. The creation of temporary jobs in the public sector, the counter cyclical objective, was an amendment to Title VI of the original legislation. (NAS 78)

CETA was created to serve the needs of the economically disadvantaged who are unable to enter the work force, due to a lack of training and access "know-how". It has evolved in the last eight years to accommodate the changing economic and political climate, by expanding categorical programs and extending eligibility requirements.

There are a number of specific training programs under CETA. Following is a description of some of those programs (See Table 7-1). Help through Industry Retraining and Employment (HIRE), is a private-sector oriented training program, presently being phased out. Designed as a targeted jobs program, particularly for veterans of the Vietnam era, over 15,000 individuals have been trained and hired through HIRE I. (Office of National Programs 80Program)

The On-The-Job training (OJT) program was established in the late 1960's, and presently consists of 30 training projects, all of which are private sector oriented. The following is an overview of national OJT:

Table 7-1: CETA SPONSORED TRAINING AND RETRAINING PROGRAMS

Program Characteristics	HIRE Title III	OJT	JC Title IV	STIP Title II
Services	on-the-job training classroom institutional training	on-the-job training classroom	on-the job training classroom vocational education	on-the-job training classroom institutional training
Funding	DOL	DOL	DOL	DOL
Clientele	veterans economically disadvantaged	economically disadvantaged	disadvantaged youth	skilled workers seeking new skills
Occupations	metal workers tool&die makers machine operators	welders assemblers other operatives	machine operators metal workers	welders assemblers

1. OJT provides skills and abilities training which enables the trainee to function successfully in the labor market.

2. OJT projects are operated by national labor organizations, employer associations, and private non-profit organizations. Generally, these organizations have some direct influence over the employment and training practices of major industries.

3. Unsubsidized placement rates for OJT graduates have been high, totalling close to 50,000 from 1976 through 1980.

Job Corps, originated in the late 1960's and reestablished in 1978, is a national system of residential centers in the United States and Puerto Rico. It provides basic education vocational training, counseling, health care, and similar renewal services to help disadvantage men and women, 16 through 21, prepare for jobs and for responsible citizenry. (ETA 80)

The Skill Training Improvement Program (STIP), a forerunner to the Private Sector Initiative Program (PSIP), has the goal of getting industry involved in the training of skilled workers. The divergences STIP took from traditional Title I CETA training were expected to pay off

in positive ways--higher earnings and more placements. STIP projects provided both initial and upgrade training. (Stevenson 78)

The Bureau of Apprenticeship Training (BAT) is a program authorized by the National Apprenticeship Act of 1937. It deals primarily with apprenticeship, a combination of OJT and related technical instruction, through which workers learn the practical and theoretical aspects of a skilled occupation. This instruction is given in local vocational schools and junior colleges. Apprentices, both men and women at least 16 years of age, train for a period ranging from one to six years and are paid while they train on the job. There are over 700 apprenticeable occupations, a few of which are automotive mechanic, electrician, machinist, operating engineer, sheet metal worker, structural steel worker, and tool and die maker. (ETA 80)

Although CETA was mandated to extend until March of 1982, its future during the 1980's is questionable given the Reagan administration's proposed budget cuts. Title VI has already been technically terminated. Whether or not other sections will suffer is questionable. If CETA is subsequently eliminated, however, it is probable that some other program will be created to promote and implement manpower training programs.

7.4.2 Private Sector Initiative Program

Title VII of CETA, now called the Private Sector Initiative Program (PSIP), is a demonstration program. It was initiated in 1978 as a $400 million effort to foster the involvement and assistance of the business community in the development of local CETA programs. (NAB 80) Title VII authorizes a variety of approaches to increase private sector involvement as well as employment opportunities for the unemployed and the disadvantaged. To achieve these objectives, the Title provides for the establishment of Private Industry Councils (PIC) which assist prime sponsors in the local development and implementation of training activities.

The "initiative" for PSIP is provided through the Targeted Job Tax Credit (TJTC) established by the Revenue Act of 1978. Under this act, an employee who hires a person eligible under CETA, can receive a credit equal to 50 percent of first year wages up to $6000, and 25 percent of second year wages up to $6000 for each eligible employee. However, the employee's normal tax deduction is reduced by that amount. (ETA 77)

Regulations of May 20, 1980 have authorized the conduct of upgrading and retraining programs under Title VII. Prior to these regulations, although an allowable activity, the eligibility criteria were restricted to the economically disadvantaged. The 1980 regulations have revised the criteria to effectively include non-economically disadvantaged people by referencing the eligibility requirement of Title II-C. (DOL ??aPSIP)

A Private Industry Council (PIC) is an intermediary organization which has the major objective of determining types of training efforts that best meet the needs of both private sector and potential employees. It serves as a forum for private sector representatives to advise and work with local CETA organizations to match job skills with those required by employers, to determine labor market needs and to design training programs to meet those needs. PICs promise to increase the cooperation of private businesses and organized labor in local human resources development programs.

PICs receive funds from U.S. Department of Labor to administer and directly operate local private sector employment and training programs. Some of these programs provide practical training, enable individuals to work for private enterprises while attending an education or training program. They also develop intern programs to provide practical training, conduct innovative cooperative education programs for youth in secondary schools, provide on-the-job training (OJT) and develop apprenticeship programs.

To qualify for Title VII funds, prime sponsors must describe proposed private sector initiatives and their integration with other CETA training programs. The description gives an analysis of private sector job opportunities including estimates by occupation, industry and local information provided by the PICs. (Brown 79) The analysis should survey employment demands in order to develop projections of long and short term labor needs and refine training programs so that it becomes more responsive to private sector labor needs.

7.4.3 Case Study of Pittsburgh PIC

The PICs are establishing a reputation for responsiveness among employers. They are helping employers gain business support for the facilities needed to train participants. The Pittsburgh Private Industry Council (PIC) is a good example of how effective PIC's can be. At this point, a brief history, description, and appraisal are given of the Pittsburgh PIC, in order to show how the Private Industry Councils really work.

The Pittsburgh Private Industry Council is a relatively recent entity. It was established in 1979, but did not become active until 1980. Employees of PIC give three primary reasons for their difficult start:

1. The perception by industry of CETA (as old programs in the CETA tradition were not very effective),
2. Red tape (involved in getting with anything in government), and
3. Fear of government.

The last reason refers to companies' fear that if they take government monies for

training or retraining, all their books must become open for government inspection. These feelings were reiterated in the 1980 National Alliance of Business (NAB) National Conference, when the participants agreed that businessmen are leery about initiating a government related program because they fear involvement with a government program and the ensuant red tape and paperwork.

Having changed that image through a major public relations campaign, the PIC in Pittsburgh appears to be a viable and constructive element in the local economy. The Pittsburgh PIC is a good example of the public and private sectors working together to achieve a common goal. There is a great diversity of interests represented on the Pittsburgh PIC executive committee. They include:

1. Cox Steel Rule Die Company
2. Liberty Precision Tooling, Inc.
3. Small Manufacturers Council
4. Nelson's Auto Service
5. University of Pittsburgh--Vice Chancellor
6. Pittsburgh Board of Education
7. Allegheny Community College
8. Bureau of Apprenticeship and Training
9. National Alliance of Business
10. Greater Pittsburgh Business Development Corporation
11. Urban League of Pittsburgh (PIC 81).

As can be seen, the interests include private industry (both large and small), public sector, and educational institutions. Together they have developed some very effective programs.

One program which is currently in progress is the "Compad International Company, Inc. Graphic and Printing Training Center." The sponsors were both Compad International Company, Inc. and the city of Pittsburgh. The funding sources are as follows: Compad International Company, Inc. for equipment, City of Pittsburgh through the Department of Development and CETA for $159,000 and $290,000 respectively. Together, they set up an intensive twelve week training program which covers the following

1. Graphic Artist--line and design drawings
2. Printing--offset

3. Platemaking--metal, paper, electrostatic

4. Stripping--layout,masking

5. Camera and Darkroom--process camera and developing

6. Bindery--Folder, cutter, pudding, and collating

7. Typesetting--photo typesetting

8. Management Development--pricing formulate, cost efficiency.

One hundred and twenty trainees were enrolled, approximately 40% of whom will be hired by Compad. The rest of the completors will be placed by Compad with their competition.

Another program in progress is the "Plumbers Local Union #27 Retraining Program." Upon receipt of labor market information from the Bureau of Employment Security showing the unlikelihood of plumbers experiencing increased employment opportunities as opposed to the very bright future outlook for plumber-welders. The union, companies, and city of Pittsburgh developed a program to retrain plumbers to be plumber-welders.

The Hospital Council of Western Pennsylvania, Allegheny Community College, and the city of Pittsburgh recently designed an upgrade training program to provide training to thirty entry level employees as respiratory therapists. The entry level employees are presently employeed as nurses aides, orderlies, dietary aides, clerks, housekeepers, and laundry assistants. (picofpit)

Davis and Ward Printing Company found it necessary to change from cold to hot presses and needed a workforce with a different set of skills. They intended to terminate most of the employees and hire those who already had the necessary skills. With funds and training assistance from the PIC and CETA, the present employees were retrained and kept their positions.

Clearly the Private Industry Council has been an effective part of the retraining practice in Pittsburgh, and illustrates methods by which retraining can be achieved in a cooperative spirit. Through the PSIP and PIC's a great deal of the potential hardships of introducing robots can be avoided.

7.5 VOCATIONAL TRAINING

Vocational education is another channel for training in the types of technical fields relevant in this discussion of robotics. Funded through federal and state appropriations for public education, vocational training occurs mainly on the secondary level.

For several states heavily dependent on manufacturing industries, data have been obtained on the numbers of persons trained in five occupational categories. Except for auto mechanics, these are some of the categories which have been identified as likely to be affected by the introduction of robotics into the workplace. The number of individuals being trained in these categories indicate that public education is not preparing people for the impending introduction of robotics .

Table 7-2: VOCATIONAL EDUCATION: TOTAL ENROLLMENT

Occupations	FY 1978 U.S.A.	FY 1980 N.C.	FY 1979 OHIO	FY 1979 PA.
Auto-mechanics	340,686	7,133	3,745	11,736
Sheet Metal	45,694	0	111	1,117
Welding/Cutting	205,486	7,203	3,293	7,942
Tool/Die Making	8,475	179	21	476
Other Metal Working Ocpns.	58,709	53	0	7,211
Total	659,050	14,568	7,170	22,482

Thus, it appears that public education as an institution has not yet recognized the future employment skill needs of society will be as robotics technology comes into wider usage.

One aspect of vocational education which presumably could play a larger role and be influential in the making of policy is the advisory council on vocational education. Established in 1968 under the vocational education amendments, advisory councils exist on both the national and local levels. These councils function to advise national and state government executives, and are "required to identify the vocational education employment and training needs of the nation (state) and assess the extent to which vocational education, employment and training programs...represent a coordinated approach to meeting those

needs". The membership on these councils, on both levels, include business, labor, education, interest group and general public representation. With such a broad collection of ideas, interests and resources, it is likely that advisory councils could direct vocational education policy in a direction that would give students today the necessary skills for a technological tomorrow.

As with other training mechanisms, more care must be taken to ensure that training in vocational schools is done in areas which will be marketable. Possible methods are two-fold. First is more active intervention by the federal government, through the Department of Labor, which could do more market research and long-range forecasting. This information would then be transmitted to the local agencies. The second method is to achieve a closer working relationship between the training program planners and private industry. This is a direction in which the advisory councils could play a role. Up until now, these councils have been relatively ineffective (and highly political), but with appropriate restructuring, they could perhaps provide the necessary link between the skills taught and the skills utilized.

7.6 JOB CREATION BY ROBOTICS

Thus far, the effectiveness and appropriateness of current training and retraining programs have been investigated, all in terms of impending robotics. The other side of the issue is that a number of jobs will be created due to the introduction of robots into the workplace, especially in programming, maintenance, and operation. Several major manufacturers of robots (Unimation, Cincinnati Milacron, Prab Conveyors) have training programs which provide participants with the skills necessary to maintain and operate robots. By examining these programs and prerequisite skills, the ease with which employees can be retrained to maintain and operate robots can be determined.

Skill requirements in the primary stage of maintenance and operation of the robots include exposure and knowledge in such areas as hydraulic valves, basic electricity, numerical controls and other areas of general plant and machine maintenance. The levels of skills required differ according to the type and complexity of the robots. The training of these individuals is the result of combined efforts on the part of the manufacturer, the robot customer, and in some cases professional training institutions. Employee training is performed in classrooms and at company sites. For example, the PRAB robot model, is a two day in-house training program, which exposes customer and in-house employees to the following:

1. Robot indoctrination. Movie on robot installation and basic robot programming.
2. Hydraulic System.

3. Mechanical.

4. Electrical.

5. Programming.

6. Review of programming.

7. Installation and hazard enclosure.

8. Tour of robot manufacturing facility.

Similar information is available on training programs for operating and maintaining PRAB Conveyors' Versatran model as well as robots produced by Unimation and Cincinnati Milacron (See Appendix).

The Cincinnati Milacron industrial robot, T3 (The Tomorrow Tool), requires skilled support personnel for correct operation and maintenance. Training programs are provided in-house and at customer site. For both maintenance and operation in-house training is provided according to the number of robots purchased: 1-3 robots-- 2 people trained, 4-9 robots--7 people are trained, and 10 or more robots--8 people are trained. Table 4 outlines the Cincinnati Milacron training program objectives and required classes for operation and maintenance. robots--8 people are trained. Table 7-3 outlines the Cincinnati Milacron training program objectives and required classes for operation and maintenance.

It should be noted that there is a difference in the skills required for operation and maintenance. Almost anybody can be taught to operate a robot with very minimal training. Although the courses needed to learn to maintain a robot are extremely technical, they do not involve skills very different from those involved in maintaining other pieces of complex machinery. Anybody who has experience in machine maintenance can easily be retrained in this field. Thus, current employees can be retrained to maintain and operate robots without an inordinate amount of time or cost.

It does not appear that the number of positions created to perform these tasks will be sufficient to have any significant impact on the number of people displaced or unemployed. While it is true that the operation and maintenance of robots will create some jobs and that the appropriate skills must indeed be taught, these new jobs are not the sole answer to the social problems which may arise from the introduction of robots.

Table 7-3: CINCINNATI MILACRON: TRAINING FOR ROBOT MAINTENANCE AND REPAIR

OBJECTIVES:	OPERATION/ TEACHING	OPERATION/ MAINTENANCE
(modes of operation)	*	*
(CRT display)	*	*
(robot hydraulic system)		*
(control modules)		*
(robot error codes)	*	*
(trouble-shooting procedures)		*
(installation procedures)		*
(capabilities of T3)	*	*
(operation of the pendant)	*	*
(cassette loading procedures)	*	*
(electronic system)		*
(control interfacing)		*
(preventive maintenance)		*
(robot safety)	*	
COURSE CONTENT:		
(safety)	*	*
(description of components)	*	*
(control panel operation)	*	*
(robot points and programs)	*	*
(CRT display)	*	*
(pendant operations)	*	
(cassette loading)	*	*
(hydraulics)		*
(electrical system)		*
(modules)		*
(robot teaching procedures)	*	
(interfacing)		*
(axis-control)		*
(alignments/adjustment)		*
(error codes)		*
(on-board diagnosis)		*
(trouble shooting)		*
(preventive maintenance)		*
(installation)		*
(functions)	*	
(commands)	*	
(error codes)	*	

7.7 CONCLUSION

Early chapters of this paper have illustrated that major changes may occur in the workforce with the introduction of the robots. This chapter has examined current programs by the private industry and public sector which could be used to ease this transition. Major problems have come to light, and they can be seen as parts of two major failures: a market failure and an institutional failure.

The market failure comes about as a result of insufficient information being dispersed in the economy. Although there has been extensive research done about the future job market, little of it is known to the public--those planning the training and retraining programs, as well as the individuals. For example, a massive amount is known about the types of tasks robots are currently able to perform. Industry has devoted considerable resources to this specific question. Yet, CETA programs and vocational schools are unquestionably training too many people for these very skills. Between STIP, OJT, and HIRE students are being trained as welders, machine operators, and metal workers, all of which have very high likelihoods of being replaced by robots.

The public sector could play a key role in solving this information failure. An effort must be made to coordinate and disseminate available information. Through periodically published, readily available and readable market information, the various training program planners, as well as individuals, could effectively plan for the future. There could be a small part of the Labor Department dedicated to keeping up with current research, and publishing a periodical, non-technical enough for the public to understand. This is a function which is not performed naturally in the marketplace, and could be a very valuable function of the public sector.

The institutional failure is one in which each of the training mechanisms has not properly prepared for the future needs of the economy. Even when the forecasts of future job opportunities and needs are available to them, the institutions are not reacting properly. This problem consists of a lack of two mechanisms within these institutions: a mechanism for receiving the available information, and a mechanism for acting accordingly.

CETA and Vocational schools have at their disposal quite a bit of information which they do not reach out and take. They are not preparing trainees for the job market, and yet firms are available to be consulted. Bringing the private sector in for consultation is one mechanism by which they can receive the proper information. Attempts have already been made in this direction, as was seen in the Private Industry Councils and vocational advisory councils. The goal is to get the proper people on these panels. Involved should be people from industry, people involved with the technical advancements, people in academia, among others.

Once changes in the economy are perceived, procedures and incentives for changing the training programs must be implemented. For example, although the importance of computers has long been recognized, Bidwell has no training courses in this field. This institutional failure can be seen in a bureaucratic framework. The goal of the institution is ostensibly to prepare people for the workforce, but the goals of the subunits within the

organization are far different. These goals are simply to get people through the programs, thus having documentation of "success." Also within these institutions is a tendency to categorize in which they "restrict the categories used to a relatively small number and enforce the first formally applicable category rather than search for the categories that might be applied and choose among them." An increase in categorization for decision-making decreases the amount of search for alternatives. This leads to a rigidity of behavior. In our context, this means that the institutions are not effectively evaluating their current training and retraining programs or considering the viable alternatives. As a solution, the institutions should make explicit the goal of changing training programs with the alterations of the economy. This can be accomplished through giving a small task force the goal of keeping up with technological changes and suggesting possible alternatives. Incentives for managers should be given to facilitate reasonable change. Strong encouragement for altering from the status quo should be given.

If solutions to the failures discussed above are actively sought, and acted upon, and a cooperative attitude prevails between the public sector, private sector, and individuals, the introduction of robotics can be a smooth and easy transition.

8. APPENDICES

APPENDICES TO
THE IMPACTS OF ROBOTICS
ON THE WORKFORCE AND WORKPLACE

June 2, 1981

I. APPENDIX A INDUSTRY POLICY SURVEY

INDUSTRY POLICY SURVEY

The following survey is to be used in a study of the social impacts of robotics currently being done at Carnegie-Mellon University. All answers to this questionnaire are confidential and will be used only to compile a statistical study of industry's policies towards robotics. No specific respondents will be mentioned in the final report. Any questions about the survey may be addressed to Dr. Leonard Lynn at (412)578-2833. Those respondents who are not presently using robotics are directed to those questions marked by a (*). The following definition of ROBOT is suggested:

"A Robot is a reprogrammable multi-functional manipulator designed to move material, parts, tools, are specialized devices through variable programmed motions for the performance of a variety of tasks"
(adopted by Robot Institute of America,1979)

QUESTIONNAIRE

*1. Industrial classification of establishment(4 digit S.I.C. if known)._____

*2. Total number of direct production workers in plant.____

*3. Percentage breakdown of total production by batch size:

____	Custom (1-100 units/yr)	11
____	Small Batch (101-1000)	10
____	Large Batch (1000-10,000)	4
____	Mass (over 10,000)	11

THESE ARE RESULTS FOR INDICATIONS OF GREATER THAN OR EQUAL TO 50%.

4. In what year did you first introduce robots into your plant? _____

5. How many robots were in use in Jan.1976?_____ 121 Jan.1981?_____ 579

6. How many robots are now being used in each of the following uses:

159	____	Spot welding
72	____	Spray painting
190	____	Pick-up and place
14	____	Assembly
144	____	Other (Specify) _____

7. Location of plant(s) where robots are used. State_____MUST BE DONE BY HAND

*8. Please rank the following in order of importance as motivating factors for the use of robotics:

THE FOLLOWING ARE AVERAGES FOR THE RESPONSES, ZEROES ARE NOT COUNTED.

2.219	_____	To reduce labor costs.
5.857	_____	To ease compliance with OSHA regulations.
6.778	_____	To reduce capital costs.
3.867	_____	To improve product quality.
3.115	_____	To increase output rate.
5.130	_____	To increase the flexibility in changing products, designs, etc.
5.667	_____	To reduce material wastage.

3.032 _____ To relieve workers of tedious and/or dangerous jobs.
6.000 _____ To remedy high labor turnover problems.
1 _____ Other_____
2 ----- OTHER

9. With the introduction of robots, has work scheduling changed in any of the following areas?

A. Average number of shifts per day:
2 _____ decreased
16 _____ no change
0 _____ increased

B. Average length of work shift per day:
0 _____ decreased
7 _____ no change
11 _____ increased

10. Has the percentage of parts rejected changed?
0 _____ increased rejection rate
7 _____ no change
11 _____ decrease in rejection rate

11. Have quality control specifications been tightened?
4 _____ yes
16 _____ no

12. Has the number of quality control employees changed?
1 _____ increased
18 _____ no change
0 _____ decreased

13. Have robots had any of the following effects on production capabilities? Please check if yes.
0 _____ ability to manufacture more complex designs
2 _____ increased efficiency in raw materials usage
6 _____ reduction in set-up times
2 _____ BOTH 1 & 3

14. Were robots placed in a new plant or in an existing plant?
2 _____ new plant
15 _____ existing plant
3 _____ BOTH

*15. Do you plan to place new robots in new plants or in existing plants during the next five years?
0 _____ new plant
20 _____ existing plant
14 _____ both

16. How were operatives made aware that robots would be introduced into their plant?
0 _____ through labor union
14 _____ by meeting with management
2 _____ workers were not notified prior to the introduction of robot
2 _____ other (please specify)_____
2 _____ COMBINATION OF TWO OF THE ABOVE

17. How far in advance was the workforce notified (in months)?_____4.35 AVG.

18. Which method was used most often to fill newly created positions?
18 _____ retraining present workers
2 _____ hiring new employees with required skills

19. If positions were eliminated, what percent of former workers were:
3 _____ transferred without retraining
10 _____ retrained for a new position within the plant
0 _____ retrained for a new position in another plant
0 _____ laid off
0 _____ retired early

THESE ARE FOR GREATER THAN OR EQUAL TO 50%

20. In any retraining efforts, did the unions:
1 _____ choose who was to be retrained
8 _____ support your intentions, but did not actually help in the retraining
2 _____ help to retrain the workers
0 _____ oppose your efforts

21. How have robots affected the level of skill required in the following areas?

A. operatives:
12 _____ increased skill level
7 _____ no change
1 _____ decreased skill level

B. maintenance:
18 _____ increased skill level
2 _____ no change
1 _____ decreased skill level

C. production scheduling:
2 _____ increased skill level
17 _____ no change
0 _____ decreased skill level

D. materials handling:
4 _____ increased skill level
12 _____ no change
3 _____ decreased skill level

E. other (please specify) _____
2 _____ increased skill level
1 _____ no change
0 _____ decreased skill level

22. Does your company have a counselor or psychologist to deal with worker problems caused by robots?
3 _____ yes, we have always had a counselor
1 _____ yes, we have had one since the introduction of robots
0 _____ yes, we have had one for the past year
1 _____ no, but we are considering it
13 _____ no, it is unnecessary

23. To your knowledge have there been psychological problems caused by the introduction of robots?

3 _____ yes
17 _____ no

24 .Since the first use of robots, have the number of production-related accidents:

2 _____ decreased
13 _____ no change
0 _____ increased

25. Was it necessary to develop new worker safety measures?

15 _____ yes
6 _____ no

26. Did the supplier of the robot help with retraining?

13 _____ yes
6 _____ no

27. How long was the retraining period?_____THE FOLLOWING ARE AVERAGES
MAINTENANCE--25.3 DAYS
PRODUCTION SCHEDULING--21 DAYS
OPERATIVES--27.3 DAYS
OTHER--20.8 DAYS

28. Have any new organizational units been created as a result of the introduction of robots or CAM?

6 _____ Yes(please identify)_____
14 _____ No

29. Were any departments consolidated or eliminated?

0 _____ Yes (please identify)_____
20 _____ No

30. How has the use of computer controlled production affected the number of managers required?

3 _____ Decreased
18 _____ No change
0 _____ Increased

31. Has an automated inventory control system been implemented?

10 _____Yes
8 _____No

32. Have new robot-specific management positions been created?

5 _____ Yes
17 _____ No

33. If yes, how were these positions staffed?

1 _____ Retraining of present managers.
1 _____ Promotion of workers.
1 _____ Hiring of outsiders.
1 _____ COMBINATION OF 1&3
1 _____ COMBINATION OF 2&3

II. APPENDIX B INTERVIEW TRANSCRIPTS

To supplement and expand on the results of the survey, a series of personal and over-the-phone interviews were conducted. Information was obtained from a total of thirty-one interviews with twenty-six corporations representing the various segments of industry in the U.S. . Included in the interviews were both firms who had responded to the written survey, and numerous major robot users who had not filled out the questionnaire.

In this section, transcripts from a selected set of interviews are presented. Within each transcript, all references revealing either an individual or corporate identity has been replaced by a randomly selected letter of the alphabet to ensure confidentiality.

The objective of the interviews was to obtain supplemental information on areas such as:

1. Motivations for using robots.
2. Decision to install robots and where to install them.
3. Major positive and negative impacts of robots.
4. Internal adaptations required to support robots.

"A" CORPORATION April 13,1981

A corporation is a manufacturer of transportation equipment. They first started using robot in 1960, and now estimate that 370 are in use in their production facilities.

The primary motivation for installing robots was to reduce total costs. The decision to invest in robots is based on the calculation of both return on investment and payback period.

The introduction of robotics has allowed the plant to increase the number of shifts. The use of robots has not led to a reduction in set-up times, they are being used to manufacture the less complex, more routine designs. They have been placed in existing plants but on new product 'ines. For safety purpose, A Corp has had to fence the robot areas off.

Workers displaced by robots are retrained within the plant, job openings due to attrition are sometimes not replaced. Some new personnel including mechanics have been hired from outside the plant.

One official indicated that the workers did experience some psychological problems. These problems were attributable to the fact that robots often broken down. A Corp's general attitude toward robots is that they are both unreliable and difficult to make them pay off.

"A" CORPORATION follow-up interview: April 24,1981

The representative stated that the variables used in the return on investment analysis are those used to evaluate robots.

Q. Is there a difference in the variables you quantify in the ROI analysis now as compared to when you started using robots?

A. Basically the same variables are in the ROI analysis. In other words, there has been no systematic attempt to extend the range of the benefits based on previous experience with robots. Some of the costs and benefits have changed though, because the robots have improved, and become more reliable. Maintenance costs have decreased.

Issue: New Plant .vs. Retrofit

The process of evaluating a robot for a retrofit is different than the process of evaluating the robot as one of several alternatives in an existing line. In the early applications, they were retrofitted. Later on, they were chosen as one of several alternatives when a new line was put together. In the retrofit situation, you already have a certain amount of hard automation present, and one does not replace it by adding a robot. When building a new line, it is a question of choosing among different types of automation.

B CORPORATION, April 20, 1981

"B" Corporation manufactures transportation equipment.

Their motivations for implementing include four equally weighted factors: 1) to improve product quality, 2) increased flexibility in changing products and designs; 3) to eliminate the problems of high turnover rates in tedious and undesirable jobs; and 4) To remedy problems of severe labor shortages.

The idea to implement robots originates within the Group Operations level which is between the corporate and the plant level. This is a production engineering group which is active in the processing and tooling. It was said that this group is characteristic of all of the major firms in the industry. The Group Operations staff also picks the application areas, makes the final installation decision, evaluates the robot's performance, and does planning for future applications.

The decision to install robots involves cost studies and payback period determination. They estimate a robot's cost at $100,000 for purchase and installation. It costs about $30,000/year including benefits to employ a worker. So a robot working two shifts will

save the firm $60,000 with a payback period of about two years. In only one case was a robot taken off-line and this was a test robot. In general, "B" Corp has a positive attitude towards robots and reports no problems other than not having enough money to buy more.

The use of robots in the plant has not affected the shifts, and no safety or psychological problems have been encountered, however, the robots are fenced off from the workers. One advantage is that the weld quality has improved which means more reliability and less repair costs for them. New organizational units have been created but not at the plant level. The number of both managers and technical people needed has increased, and these positions are filled by in-house people. But no robot specific management positions have been created.

"B" CORPORATION follow-up interview, APRIL 26, 1981

Even for the first robot applications, management decided that this type of technology was needed to get high quality in the product. Robots were brought in to improve quality and to upgrade technology. It was not done on a cost saving basis. The first applications were part of a development process for new technology. Later applications were done for quality improvement reasons.

There is motivation throughout the company to improve the quality of our products, from the very top on down. Robotics is seen as a way to accomplish this.

Improved production flexibility was also an important consideration. Through a financial analysis, they saw that this programmable automation would only pay off after the second model change, but they decided to go ahead with it anyway. They are adding new models and making face lifts without buying new machines.

They knew they could achieve the quality improvement. They saw other auto makers in the U.S. and in Europe doing it. They knew what the equipment could do, and what problems they were having. They did not try to quantify quality in the conventional financial framework. They just went ahead with these systems. The spokesman said it is just something you have to do to get the quality level.

Now they say they are the leaders in some aspects of product quality. If all of their earlier decisions were based on cost savings, robotics use would have been greatly reduced. They would have had to look for other ways to improve our product, and none of the alternatives seemed to work very well.

Top management is committed to robotics. If they were strictly going by dollars they would have had a much more difficult time in developing these applications. Another

transportation manufacturer are spending billions within the next few years on new tooling. He said this is not based on cost saving alone. Competitive reasons are very important. They want to catch up with the Japanese and with us.(B Corp)

The reason the Japanese are so far ahead is that they are willing to invest in a project which may take up to ten years to justify. In general, the U.S. is lagging in quality partly because of the use of conventional, short term techniques for justifying our expenditures.

They are also getting people out of work that is tedious and monotonous. People are absorbed into other jobs. Between reabsortion, and the attrition rate, there has not been a problem with labor.

"C" CORPORATION, April 21,1981

"C" Corporation manufactures transportation equipment.

DIVISION "A"

Division "A" produces major component parts for "C" Corp. The major motivations to use robots in this division is to save on labor costs. Increased production flexibility is not a major concern. The idea to use robots originated in the plant.

Most of the machines are dedicated. They do not require reprogramming. In many application, robots represent a type of overkill, since their general purpose capabilities exceed what is really needed. In most applications, they do not need a high technology robot.

The need for robots evolved out of problems with hard automation. In this particular parts handling application, robots were needed because the hard automation could not handle the job.

Robots are evaluated by a comparison of time savings and cost avoidance analysis. This is more direct than return on investment.

Eight new, sophisticated robots were installed at once in a new plant that was producing a new product. No one had worked with this type of robot before. There were severe start up problems because everything was new and there was a lack of commitment on everyone's part to the bring the system on line. This included both maintenance and operations people, as well as management.

In the early training phase, there were big problems because they could not get people dedicated to the training. Management would pull peopled in and out of the training course. Once they completed the course, and were assigned to the robot, there were often rotated after a short period.

This problem with training seemed surprising since they apparently have the highest percentage of skilled trades workers of any plant in the division (if not the corporation). Their were training problems because people were shifted around too often, and too much was started up at once, not because of people's basic ability to master the necessary skills.

It was said that when robots have been retrofitted into existing facilities then there were far fewer problems with start up and retraining. Some of the union people do not want to work with the robots because they think they eliminate jobs. On the other hand, they insist that they be the robot repair people and operators.

DIVISION "B"

Division "B" produces small components parts for "C" Corporation. Four materials handling robots were installed in 1974, and today they have nine robots (five pick and place, and four for die casting).

The idea to use robots originated within the plant. The main motivation was to reduce direct labor costs at plant level. Initially, they based the robot purchase decision on a payback analysis. Now a return on investment calculation is done.

In the six years that they have been using robots, they have not changed their financial analysis dramatically. They still quantify the same basic variables as when they started robot cost and direct labor savings. As they have gained more experience with robots, they have become more cognizant of indirect costs associated with applications engineering and training our skilled trades people. They have not made any attempt to quantify these costs in their financial analysis as of yet, although they are more aware of their existence.

For them, the benefit side of the coin is fairly well defined. It is measured in terms of direct labor saving. This is due to their particular applications of robots. They are integrating them into existing automated systems. The robots are not the controlling factor on output rate, so their use has not resulted in an increase in output. Material handling robots do not affect product quality. They are still being used for the same activity for which they were originally installed, so production flexibility has not been an important concern. So the benefits are well defined in terms of cost saving resulting from reduction in direct labor.

As they continue to use robots, he thinks that they will learn more about indirect cost, and not so much about indirect benefits, at least in the present applications. He realizes they have missed many of the intangible indirect cost associated with bringing robots on line, and maintaining them. He thinks they should be placing more emphasis on the cost of maintaining robot systems. Up to this time, the cost of maintaining the robot systems, and

of training people has been ignored in their cost justification. They will soon begin to use historical information on indirect costs in future decisions.

Their maintenance requirements were higher then expected, but not because of robot reliability. Most of the problems occurred at the robot machine interface. The robot can not compensate for many things in the way that a human can. For example, they can not fix jammed parts in the line, so a maintenance person has to go in and do it.

They do not have NC equipment in the plant, aside from a few machines in the tool room. Robot maintenance was assigned to their electrical control systems people. They have been able to pick up the necessary knowledge to maintain robots without any problems. They have sent the appropriate hourly people to school to learn how to operate the machines. In short, training their hourly workers to use and maintain robots has not been a major stumbling block. His off the cuff feeling was that it is easier to teach someone to use (although not necessarily maintain) a robot then a NC machine tool.

DIVISION "C", April 10,1981

The Division "C" plant has had robots in use for the past 12 years. In 1976, there were 26, but presently, there are 22 in use. The major motivations for their use are: manpower savings(productivity), consistency of weld, and no absenteeism.

The decision to install robotics is made at the corporate headquarters, although it does require mutual approval between headquarters and the plant. A study of payback period is done and the workers are consulted when deciding on implementation.

"C" Corporation does have an automated committee studying robotics. The overall impression of robotics at "C" Corp is positive. They are attempting to install robots where they can replace distasteful jobs, such as painting applications.

One problem that has occurred is that there has been more down time then expected. Each occurrence usually only amounts to a fraction of a minute though. Maintenance of the robots, then, has been the major negative impact of robotization.

"E" CORPORATION, April 13, 1981

"E" Corporation is a foreign based manufacturer of transportation equipment with a plant in the U.S. They purchased two robots in the summer of 1980 and still have only two. Although they have no big plans for robots until maybe 1985, they are optimistic about robots within their existing plant. Their motivations are to reduce labor costs and to improve reliability of the production process. The decision for implementation is made on plant level following a proposed costs and benefits analysis. The only time a corporate OK

is needed is when the plant needs financial support for the project. These robots are being used on a test basis for spot welding. The tests will help them compare the robots made by two different manufacturers. They are trying to decide which to buy.

One of the biggest questions is what to do with the displaced workers. The spokesman suspects a small layoff along with an addition of skilled maintenance people. For the skilled positions, they would probably have to hire from outside the plant because he feels it would be too difficult to retrain the present workers, as a training program could take up to four years. The plant group which will maintain the robots is the Welder's Equipment Maintenance and Repair group.

"F" CORPORATION, vApril 23, 1981

"F" Corporation is a diversified manufacturer of capital and consumer goods.

In the first applications, the novice robot users only look at saving direct labor cost in their ROI analysis. Inexperienced users only pick up on direct labor cost because they do not know what else will be affected. The experienced users like ourselves have learned that improvements in product quality and productivity, and reduction in indirect requirements CAN be quantitied, and are worth dollars.

After two years of robot use, we saw the light. We showed the benefits extended beyond labor savings, and that we could quantify it.

Today, we are still looking for a three year payback. If you can get a three year pay back on a leading edge technology like this, you have it made.

We need management who has guts enough to say there is more potential than the direct savings the financial people will give us credit for. The management who had enough guts to justify their robot applications on the basis of longer run saving are now sitting on top of the world.

After four years of evaluating robot applications, we have not changed the basic system of financial evaluation much, but we have a much better idea of the real costs and benefits. We are convinced we can put dollars on improved quality, product life, and savings in indirect materials.

As a side comment, sometimes the productivity increase is so damn high we can justify the robot without removing direct labor.

Four year ago, people within our plants said that robots did not meet their needs. Today, these same people are installing 3 or 4 at a time.

It has taken over three years to build management support for robots. Now every management level supports robots. In my view there is no excuse for not putting robots into our plant.

All the novice users will go through the cycle of viewing their initial applications strictly in terms of direct labor cost, and then expanding their estimates of the benefits. They may go through this cycle faster then we did, since there is more information available today. You can read about robot applications in books. You can buy guides which compare industrial robots whereas, we had to write our own guide four years ago. Today, people are starting with a larger information base.

"F" CORPORATION: Division "A"

"A" division, is a potential user. Their motives include reduced labor costs and increased efficiency. He also added that there is a safety factor to consider when dealing with their products which is a motive for "F" Corp because of OSHA regulations. They are presently considering robots for packaging their products. Estimates are that three or four people will be displaced, yet they will not be laid off. Their plans are to stop replacing retirees until they eventually work down to a minimal labor force. The decision making process is carried out by the engineering staff of the home office which is involved in all production design projects and decisions.

"G" CORPORATION, March 11,1981

"G" corporation is a large manufacturer of capital goods.

The main motivations for using robotics were to relieve workers of unpleasant and dangerous jobs, and to "keep up" with the Japanese. He also stated that these motivations only apply for the first generation of robots and that the next generation will be used to improve product quality and to reduce labor costs. He felt that the productivity problem, the technological advances with micro-processors, and the shortage of skilled trade workers are the main motivations on an industry-wide scale.

He said that every new plant will have a robot in it where applicable. They will also install robots into exist- ing plants. He suspects that the reduction in set-up times will be a positive impact in the future.

The labor force was notified at least six months in advance of any installations. They have not experienced any safety or worker psychological problems due to robotization. No workers have been laid off, nor will any be laid off in the future because of robotization.

When positions were eliminated due to the introduction of robotics, the workers were retrained for other positions within the plant. The new positions created by robots were filled jointly by displaced workers and other in-house people. There has been a slight increase in the skill level required by the new positions. The worker's job satisfaction level has increased because many difficult, dangerous, or unpleasant jobs are now much easier, safer, and less tiresome with the use of robots. He stated that workers should not fear loss of their jobs because, within "G" Corporation, there is a labor shortage, not a labor surplus.

There have been new organizational units created by robotics. Two such units are a corporate planning group and a robotics group. He said that the number of managers required due to robotization has greatly increased, although no new robot-specific management positions have been created.

"H" CORPORATION, March 10, 1981

"H" corporation is a diversified manufacturer of capital goods. "H" Corp had 6 robots in use during 1976 and they have 12 in use at the present time. The spokesman projects that they may install as many as 50 additional units in the next two years.

The most important motivation for installing robots was to reduce labor costs. Other factors that "H" Corp deemed important were: to increase output rate; to improve product quality; and to reduce material wastage. Moderately important were: to comply with OSHA and to increase flexibility. He saw the reduction of labor turnover problems, and the reduction of capital costs as being unimportant factors He thought increasing productivity should have been included on the written survey as a motivation. Presently, their corporate headquarters has a positive impression of robots and their capabilities. Presently, their corporate headquarters has a very positive attitude toward robotics.

"H" Corporation's policy requires that all capital expenditures be evaluated according to a set of standard criteria. Robot implementation decisions are evaluated in this standard method. Some of the techniques used are: calculation of pay- back period, return on investment, lease vs. buy, and a host of other standard financial management techniques.

The major effect of robotization on labor was positive. "H" Corp experienced no labor problems,psychological or other- wise. No employees were laid off, rather they were displaced to new jobs. He indicated that no employees will be laid off in the future due to robotization. The workers accepted robotization because many of the times unpleasant jobs were being abolished.

The effects on production were also positive. He cited reliability as an extremely

desirable quality added to the production process by robots. Some robots were installed in one of their plants in 1968 and they ran for two shifts a day, seven days a week, for seven straight years with no problems. He also saw robots being very useful in handling large bulky parts. He added that actual productivity was even greater than what they expected.

When asked if there were ever any negative effects of robotization at "H" Corp. He responded that back in the late sixties they had a few safety problems but they were corrected immediately. He did not see any other bad side effects of robotization.

My final question to him was that if there are so many easily identifiable benefits to the organization by instal- ling robots and so few drawbacks, why do they have so few robots. He stated that the reason lies with management at their corporation and their views of robots. Many managers are resistant to change of any kind if current operations are satisfactory. Conservatism rules in the business world and especially at "H" Corp. When deciding how to use capital, risk is valued as undesirable. That was the major stumbling block for robotization in their organization and in American business in general.

"H" CORPORATION:DIVISION A, April 20,1981

Division "A" has four plants using robots. However, only one of the four is thoroughly knowledgeable about the internal workings of robots, to the point where they would repair integrated circuit boards without shipping the components back to the factory.

The plants that do not use robots think they are sophisticated black boxes that are too complicated to maintain, and that are unreliable. The plants that do use robots do not have this view.

To counter this reluctant attitude among non users our division is sponsoring a robotics and automation workshops. They want to develop the analogy between NC machines and robots.

All plants are being asked to draw up a five year plan for the use of robots and automation. If their is not a strong motivation within the plant to upgrade technology, then the division will try and promote this idea. In essence, there is a concerted effort within the division to promote robot technology, and to get the plants interested in using it.

From a maintenance point of view, a robot can be viewed as an NC machine tool. Their NC maintenance people have be able to make the transition easily. Their NC people know how to program, and how to troubleshoot. After the two week training program given by the robot manufacturers, they are knowledgeable about robots. However, if some guy with

little machine repair experience were picked off the street, and asked to train to repair a robot, the transition might be difficult.

In plants where they do not have experienced NC personnel, it is harder to draw on people to train to maintain and operate robots.

At present, he says the manufacturers can accommodate his needs for training his people to use and to maintain robots.

"I" CORPORATION, April 22, 1981

"I" Corporation is a manufacturer of appliances that first began considering robots 1968-69. The first application was conceived and implemented at the plant level. The decision was made on a strict ROI basis, looking at labor saving only.

The robot did the job satisfactorily, but then the job changed, and it was not necessary to run the machines full time. The robot was no longer deemed necessary, and was taken off-line, and left idle. The machine was not utilized for a long while because no other engineers within the plant of division wanted to invest the time to get it operational for a new application.

Up to now, a robot was bought for one specific job. If the job changed, the robot was taken off-line, as illustrated above. It would not be used again until a new sponsor was found within the plant or somewhere else in the division.

If a production engineer wants to use a robot, he has to make a request for it. He says they are short of the type of people who want to develop the application and install it. He says people are too busy putting band-aids on old equipment. There is little time to think about using new technology. The good fellows who would be the types who could use robots effectively are too busy making sure that the old equipment is working. They are not able to plan for the future. He said, "With American Industry running lean and mean, entrepreneurs are few and far between."

Until very recently, all purchases were done on a strict ROI basis. He said, " We were very bottom line oriented." Last year, the vice president of the division said we need more robots in order to test out if they really had a place in our operations. After that announcement, the number of applications for robot use increased significantly. The request did not specify the large ROI's that they looked for in the past. Those who really wanted to work with flexible automation went back and redid their analysis to make it look more appealing. They went ahead with a several of the requested applications anyway, even though they did not have as large a ROI as they would have required in the past.

There were no major problems in getting the maintenance and operations people to get used to robots. In his view, robots are mostly hydraulic systems, and electric motors. The type of machines they are using have simple logic devices. The maintenance people can learn to do this without a great deal of difficulty.

"J" CORPORATION, April 23, 1981

"J" Corporation manufactures service industry equipment. They are currently using three robots two of which have been in the die casting operation since 1977. The motivations for using robots comes froms the operational level within the plant. This has been the case for both existing and newly planned applications. Corporate headquarters is lean in technology. They have not pushed the motivations because they do not have the technical background in process improvement. They have not resisted attempts to use robots, either.

For the die casting application, the motivation was to replace an unpleasant job where there was a labor turnover. A simple, somewhat fragmented payback analysis was done. New robot applications are being planned. There is a strong push by financial people for better substantiation of cost and savings. Now they are starting to use a discounted cash flow analysis, and are looking for an internal rate of return greater than 25 percent.

They still only quantify direct labor savings. They will not modify the categories of costs of benefits based on their initial experience. Product quality and increases in productivity will not be quantified in next rounds of financial analysis, but they should be quantified sometime. "As we look into the the future, these issues will have to be addressed."

"K" CORPORATION, April 23, 1981

"K" Corporation is a mass producer of small high precision consumer products. At present, one robot is being used for welding applications. They are conservative in their approach. They do not view robots as a curiousity. They will not use them unless they are economically viable. The one robot now in use does not cause much reaction from the workers because they are already highly mechanized.

They have designed our own dedicated production and assembly equipment that suits our needs. They are producing high volume items which have a large number of very small parts. Today's robots are not applicable to this type of work. They cannot handle the small parts, or the large volumes. They are in a totally different arena then the automotive or appliance people.

One application where they do use a robot is to do welding on a product possessing few parts and low volume.

We do not have plans for robots other than the one application where it is now being used. They view their welding application as a trial balloon. We only run parts through the robot welder when it is economical to do so. As a result, they are gaining robot experience at a relatively low rate.

"L" CORPORATION, April 21, 1981

"L" Corporation manufactures component parts for airplanes. The primary motivation to use robots has come from the Corporate level. They have said to use robots, and it is for the people at the plant to figure out how and where. Until recently, management gave no encouragement for a robotic program. He commented that in general, management wanted to an impression to outsiders that they were innovative, but, internally did things to discourage innovations. For example, people would be penalized if a new development program did not work out.

Now the word has come out to "Do something about using robots." He even has robot quotas to fill. However he must still be cautious because of a perception that " The first application better be darn successful".

There is a problem with getting appropriations approved. He has to do an ROI analysis at the plant level. The corporate financial officers only look favorably upon an ROI that shows a fairly fast payback. He says this unfortunately ties in with direct labor rates. ROI will not be favorable unless there is a dramatic decrease in direct labor. He says they are trying to use robots hostile environments where there is a problem with dust or fumes. There are problems with working conditions, and labor turnovers in these type of applications because they do not show the direct labor savings they are looking for.

The corporate financial people do not buy the argument of improved product quality either, since they say they are already making a high quality product. Arguments such as quality improvement, or increased flexibility seem nebulous, and do not carry as much weight as direct labor savings. He says this type of emphasis is applied to the evaluation of all new technologies, not just robotics.

"P" CORPORATION, April 10, 1981

P Corp. manufactures electrical equipment. They do not currently use robots. Their major motivation for installing robotics is to reduce labor costs. He said that they plan to place robots in new plants so that they don't have to worry about the unions. He seemed overly concerned with the high cost of labor. In the decision making process, an economic justification and an analysis of payback period is made at the company headquarters.

"Q" CORPORATION, April 21,1981

"Q" Corp is a primary and fabricated metals producer. Several years back the corporation started to promote within the company the idea of using industrial robots to the various plants. Today, he classifies their corporation into three categories:

1. Plants which have robot experience, and which are now mostly self sufficient in supporting their own applications. These plants have picked up the ball and run with it.

2. Plant which are not using robots, but which are pushing the technical center for assistance in developing.

3. Plants which do not use robots, and which are not really interested in doing so now.

Robot applications are based on a ROI analysis. He clearly states that there primary motive is to eliminate dangerous and unpleasant jobs. He says that there is no problem with incorporating this into an ROI framework. (Interviewer's Comment: Although he did not say it, it appears the analysis is based strictly on direct labor savings).

The robots which have been installed are less sophisticated then some of their other equipment. There is no technical problem with operating or maintaining them.

MANUFACTURER "A"

Manufacturer "A" sees the main motivations of their customers as reduction in the number of hazardous jobs and improvement in productivity and quality. Eighty percent of their customers are in the auto business. The applications include loading, inspection, pick and place, and and palletizing among others. Most of the time A has contact with main plant or corporate headquarters first. Seventy to eighty percent of their robots are placed in existing plants. As for a general breakdown of the size of the customer's plant, A finds that 60% of them are large and 40% are small manufacturers. The customers look at payback period most often but also noted is the fact that robots can run longer and more time-efficient than humans since they do not take any breaks.

"A" offers help in training workers to operate and maintain the robots, but it is over and above the cost of the robot. Most customers want this program. A also employs full-time instructors for this purpose.

The robot market is experiencing 35-40% growth per year and "A" is looking for 100% growth from 500 hundred sales in 1980 to 1000 in 1981. The government may influence this goal they allow write-offs for capital equipment.

The general attitude of most customers is positive although there have been cases of a

robot being taken off-line. Most of these cases involve robots that were purchased five or more years ago because the customer's needs and the types of robots available have changed substantially since then.

MANUFACTURER "A" follow up Inteview, April 24,1981

Novice users almost always restrict cost justification to direct labor cost. He claims that an additional 35% savings could be justified if indirect costs were accounted for.

As more and more companies work full time in robotics, they tend to learn more about quantifying indirect costs. He claims that novice users will expand their justification analysis as more and more information becomes available.

He says that he has seen numerous cases where users have expanded the categories of quantifiable cost savings after their initial applications. When asked how long it takes for a user to realize this, he said their was no general answer. It depends on experience.

He feels that the most important issue holding back the robotics market is the lack of trained personnel who know how to use robots and develop their applications. He points out that almost no university has an undergraduate program where students can get experience with robots. The one exception is a Macomb Community College (which focuses on apprenticeship training, not on management). Every school offers undergraduate students courses in data processing and micro processors, but even the schools with robotics programs do not have formal programs which give students experiences with robots.

Until you start educating people about the new manufacturing technology, they will have a narrow view of its applications and benefits. As a result, novice users of robots always justify their applications on the most narrow criteria until they learn more.

III. APPENDIX C SUPPORTING DATA FOR CHARACTERIZATION OF ROBOTS AND MANUFACTURING JOBS

III.1 DISTRIBUTION OF EMPLOYMENT BY SIZE OF FIRM

The percent of total employment within establishments of a given size class is shown for the four industries within the metalworking sector in Table 8-1. To interpret the table, we see that 34.8 % of the employees in Fabricated Metals are employed in firms with 99 or fewer total employees. There is a notable difference in how employees are distributed between small and large establishments within the four industries. Almost 80% of employees in transportation equipment, and 60% of employees in electronic machinery work in establishments with 500 or more people. In contrast, over 70 % of the employees in fabricated metals work in establishments with 500 or fewer people.

Table 8-1: DISTRIBUTION OF EMPLOYMENT BY SIZE OF FIRM IN THE METALWORKING INDUSTRY

SIC CODE	Total Employment[45]	Percentage of total employment working in establishments with: 1 to 99 people	100-499 people	500-999 people	1000 and more people
34	1,621,812	34.8%	37.9%	28.0%	15.8%
35	2,240,460	28.4%	26.0%	15.2%	30.4%
36	1,827,937	12.6%	27.6%	16.8%	43.2%
37	1,863,233	07.7%	14.5%	7.9%	69.9%

SOURCE:COUNTY BUSINESS PATTERNS,1978, UNITED STATES SUMMARY. BUREAU OF THE CENSUS, 1981.

[45] Total employment figures given in this table are derived from an independent count from the figures given in Table 5-12. The two sets of figures differ slightly.

Table 8-2: BREAKDOWN OF SIC CODES 34-37

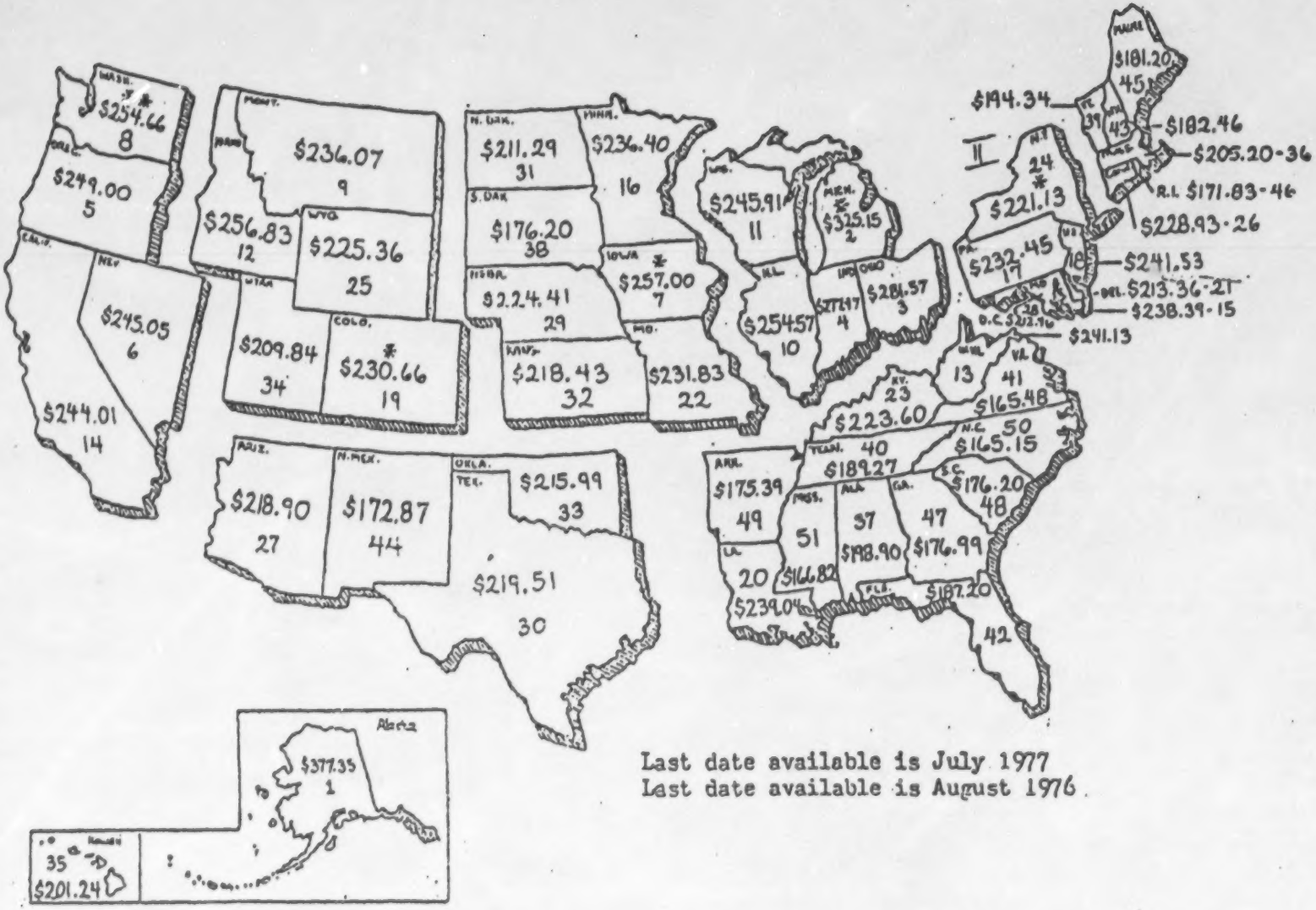
(Data for 1977)

Source: Census of Manufacturing

SIC Code	Industry Name	Number of Employees (000's)	Value Added ($Mil)	Value of Shipments ($Mil)
34	Fabricated metal products	1712.9	50126.8	97929.1
341	Cans and shopping containers	72.1	3432.3	9029.5
342	Cutlery, hand tools, hardware	166.9	5161.7	8494.7
343	Heating, plumbing fixtures	52.0	1530.0	3013.5
344	Fabricated structural metal products	422.7	11685.9	24822.8
345	Screw machine products	104.2	2857.8	5070.0
346	Metal stampings	458.9	14056.8	27080.0
347	Coating and engraving	91.8	1920.4	3363.3
348	Ordnance accessories	71.1	1775.2	2683.6
349	Misc. fabricated metal products	273.2	7706.7	14371.7
35	Machinery, except electrical	2082.2	66572.0	122211.5
351	Engines and turbines	129.6	4917.4	10376.5
352	Farm, garden machinery	150.6	5487.4	11830.6
353	Construction, [illegible]aterial handling	330.6	11753.1	23554.9
354	Metalworking machinery	293.3	7791.5	12913.1
355	Special-industry machinery	190.7	5441.2	9520.2
356	General industrial machinery	307.0	9457.2	16124.1
357	Office, computing machinery	268.6	10443.9	17531.1
358	Refrigeration service machinery	192.2	5984.6	12462.1
359	Misc. machinery, except electrical	219.6	5295.7	7898.9

36	Electrical machinery, equipment	1707.5	49708.3	87602.7
361	Transformers, distribution equipment	115.8	3335.6	5779.6
362	Electrical industrial apparatus	198.7	5569.3	9570.5
363	Household appliances	162.3	5274.6	10737.0
364	Electrical wiring, lighting	165.4	4704.0	8288.9
365	Radio, TV equipment	98.2	3128.5	6974.5
366	Communications equipment	451.7	13939.9	22404.5
367	Electronic components	367.7	9110.8	15139.0
369	Misc. electrical equipment	147.7	4645.6	8708.7
37	Transportation equipment	1763.3	64166.4	166795.2
371	Motor vehicles, equipment	873.0	36880.9	117455.6
372	Aircraft and parts	430.9	14767.5	26087.6
373	Ships and boats	219.5	4679.3	8302.6
374	Railroad equipment	56.7	1912.2	4304.7
375	Motorcycles, bicycles, parts	15.3	361.0	933.5
376	Guided missles, space vehicles	118.3	4358.2	6527.4
379	Misc. transportation equipment	49.6	1207.3	3183.8
38	Precision instruments	555.4	18692.1	28707.9
39	Misc. manufacturing industries	435.7	10197.7	19013.3
	TOTALS (34 - 39)	8257.0	259463.3	522259.7

Table 8-3: AVERAGE WEEKLY EARNINGS OF MANUFACTURING PRODUCTION WORKERS, 1977



Last date available is July 1977
Last date available is August 1976.

Table 8-4: STATES WITH HIGHEST AND LOWEST WAGE RATES

Table 8-5: AVERAGE HOURLY WAGE BY SIC CODES, 1980

AVERAGE HOURLY WAGES BY INDUSTRY, ALL OCCUPATIONS, 1980

SIC Code	Industry	Average Hourly Wage
34	Fabricated Metal Product	7.09
341	Metal cans & shipping containers	9.27
342	Cutlery, hand tools & hardware	6.80
343	Plumbing & heating, except electric	6.41
344	Fabricated structural metal products	6.95
345	Screw machine products, bolts, etc.	6.71
346	Metal forgings & stampings	7.96
347	Metal services, nec.	5.80
348	Ordnance and accessories, nec.	7.09
349	Misc. fabricated metal products	6.75
35	Machinery, except electrical	7.66
351	Engines & turbines	9.27
352	Farm & garden machinery	9.22
353	Construction & related machinery	8.66
354	Metalworking machinery	8.17
355	Special industry machinery	7.52
356	General industrial machinery	7.97
357	Office and computing machines	6.73
358	Refigeration & service machinery	7.23
359	Misc. machinery excep. electrical	7.82
36	Electric & electronic equipment	6.96
361	Electrical distributing equipment	6.98
362	Electrical industrial apparatus	7.12
363	Household appliances	6.99
364	Electrical lighting & wiring	6.43
365	Radio & T.V. equipment	6.43
366	Communication equipment	7.94
367	Electronic components & accessories	6.05
369	Misc. electrical equipment & supplies	8.00
37	Transportation equipment	9.34
371	Motor vehicles & equipment	9.89
372	Aircraft and parts	9.27
373	Ship & boat building & repairs	8.18
374	Railroad equipment	9.92
376	Guided missiles, space vehicles	9.22
379	Misc. transportation equipment	6.87

Source: Employment & Earnings
March 1981
Bureau of Labor Statistics

Table 8-6: OCCUPATIONAL EMPLOYMENT STATISTICS SURVEY

All occupational employment data in this appendix is taken from the Occupational Employment Statistics (OES) Survey. The following description of the survey is abstracted from Occupational Employment in Manufacturing Industries, 1977, BLS Bulletin 2057, and The Handbook of Methods, Chapter 7, BLS Bulletin 1910.

The survey is designed to collect data on occupational employment of wage and salary workers by industry in nonfarm establishments.

The OES program has three elements. Briefly, they are as follows:

1. The Occupational Employment Statistics Survey--a mail survey designed to collect current data on wage and salary employment by occupation and industry from nonfarm establishments.

2. The National/State Industry-Occupation Matrix System--a set of tables (one for each State and the District of Columbia) that, for a specific period of time, show total employment in specific occupational categories, cross-classified by industrial sectors and class of worker categories, which are used as a principle tool in preparing estimates of current employment and projections of occupational requirements for States and sub-State areas.

3. The State and area Occupational Projections Program--a program of guidance and assistance to State employment security agencies in developing estimates and projections of occupational requirements for States and areas.

The Bureau of Labor Statistics (BLS) provides the procedures and technical assistance for the survey, the State employment security agencies collect the data, and the Employment and Training Administration provides administrative support. In 1977, 43 States (including the District of Columbia) participated in the survey compared with 29 States in 1974 and 16 in 1971. BLS conducted a supplemental survey in 1977, with the financial aid of the National Science Foundation, to develop data for the nonparticipating States.

Survey Procedures

The survey is conducted over a 3-year cycle; manufacturing industries are surveyed in one year and nonmanufacturing industries in the other two years. Data are collected from a sample of establishments primarily by mail; telephone followups and personal visits are made when an establishment

response is critical to the survey. The survey is based on a probability sample, stratified by industry and size of employment, designed to represent the total or "universe" of establishments covered by the survey. Data are requested for the pay period including the 12th of the reference month, which is standard for all Federal agencies collecting employment data.

For the 1977 survey of manufacturing industries, 22 separate questionnaires were developed, each having detailed occupations related specifically to a particular industry's activity. For example, "patternmaker" was surveyed in only three industries--apparel, furniture, and leather. Cross-industry estimates, therefore, cannot be developed for most detailed occupations because not all detailed occupations were included on every survey questionnaire.

Concepts

An establishment is an economic unit, such as a factory, which processes goods. Generally, it is at a single physical location and is engaged predominantly in one type of economic activity. Where a single physical location encompasses two or more distinct activities, these are treated as separate establishments if separate payroll records are available and certain other criteria are met.

Employment includes full- and part-time workers; workers on paid vacations or other types of leave; workers on unpaid short-term absences (i.e., illness, bad weather, temporary layoff, jury duty); salaried officers, executives, and staff of incorporated firms; employees temporarily assigned to other units; and employees for whom this unit is their permanent (home) duty station, regardless of whether this unit prepares their paycheck. Excluded from coverage are proprietors (owners and partners of unincorporated firms), unpaid family workers, and workers on extended leave (i.e., pensioners and members of the Armed Forces).

Sampling Procedure

The sampling frame for this survey was the list of units in the specified SIC's as reported to the State employment security agency. Because each cooperating State selected its own sample, reference dates of the sampling frame varied according to the last updates to the frame and the time sampling took place.

Response

Including the results of all States, there were 148,136 final eligible units in the sample (i.e., excluding establishments that were out of business, out of scope, etc.). Usable responses were obtained from 83,814 units, producing a response rate of 56.7 percent based on units and 55.4 percent based on employment. Subsequent to preparation of the national estimates, additional data were received by States and used in preparing State estimates. Response rates in most States were significantly higher than the response rate used to develop national estimates.

Reliability of Estimates

Estimates from the sample may differ from results of a complete survey of all establishments in the sampled lists. Two types of errors, sampling and nonsampling, are possible in an estimate based on a sample survey. Sampling error occurs because observations are made only on a sample, not on the entire population. Nonsampling error can be attributed to many sources, e.g., inability to obtain information about all cases in the sample; differences in the respondents' interpretation of questions; inability of respondents to provide correct information; errors made in recording, coding, or processing; errors made in estimating values for missing data; and failure to represent all units in the population.

Table 8-7: COVERAGE OF OCCUPATIONAL EMPLOYMENT STATISTICS SURVEY

State	34	35	36	37
New Jersey (NJ)	All	All	All	No Listing
New York (NY)	All	All	All	All
Pennsylvania (PA)	All	All	No Listing	All
Georgia (GA)	All	All	All	All
North Carolina (NC)	All	All	All	All
Tennessee (TN)	All	All, Except 357	All	No Listing
Indiana (IN)	All	All	All	All
Illinois (IL)	All	All	All	All
Michigan (MI)	All	All	All	All
Ohio (OH)	Not Available	Not Available	Not Available	Not Available
Wisconsin (WI)	All	All	All	All
Texas (TX)	349	352 354 355 357	No Listing	All
Missouri (MO)	All	All	All	371
California (CA)	All	All	All	All

OCCUPATIONAL EMPLOYMENT BY REGION FOR SELECTED METALWORKING OPERATIVE CLASSES, 1977[A]

OCCUPATION	Region[B] SIC	II NJ	II NY	III PA	IV GA	IV NC	IV TN	IV IN	V IL	V MI	V OH	V WI	VI TX	VIII MO	IX CA	National
Assembler-A	34	540	730	190	60	130	1,080	725	1,074	420		320	220	300	1,851	15,860
	35	750	180	70	210	260	90	256	3,067	410		270	--	190	735	10,950
	36	150	190	--[C]	140	260	570	3,068	--	--		25	--	490	1,175	20,280
	37	--	1,780	--	580	--	--	685	--	--		365	2,670	340	4,782	19,530
Assembler-B	34	1,300	1,710	270	330	620	1,120	919	3,915	1,630		1,350	540	410	4,291	34,470
	35	1,820	980	130	240	630	4,550	935	2,588	800		1,290	--	330	1,421	26,040
	36	1,400	930	--	530	1,810	8,520	933	773	90		955	--	650	4,602	37,580
	37	--	430	--	580	--	--	1,016	--	630		155	1,050	--	2,858	24,930
Assembler-C	34	4,150	4,390	440	1,400	1,580	--	3,535	6,217	6,960		4,680	640	2,070	5,909	84,790
	35	2,540	6,390	150	970	4,200	--	4,370	7,126	6,900		4,455	800	2,370	6,543	101,820
	36	11,310	17,980	--	2,140	10,120	--	25,892	24,184	9,410		8,070	--	7,380	17,216	275,030
	37	--	8,060	100	7,040	2,950	--	14,680	8,084	64,670		6,935	4,990	10,600	12,367	214,200
Assembler-A Electrical & Electronic	34	--	--	--	--	--	--	--	--	--		--	--	--	--	--
	35	260	900	20	--	280	--	142	556	610		385	--	60	2,482	14,210
	36	1,030	1,910	--	60	--	1,280	462	485	470		440	--	--	6,361	27,710
	37	--	330	--	--	--	--	--	--	--		--	270	--	1,358	4,560
Assembler-B Electrical & Electronic	34	--	--	--	--	--	--	--	--	--		--	--	--	----	--
	35	1,040	1,640	20	330	240	--	91	619	550		545	--	260	4,248	29,970
	36	2,240	5,880	--	1,230	1,240	1,280	3,023	3,999	830		2,285	--	1,870	15,081	80,140
	37	--	850	--	110	--	--	--	--	50		25	490	--	1,367	5,240
Assembler-A Electro-Mechanical	34	--	--	--	--	--	--	--	--	--		--	--	--	--	--
	35	--	220	--	--	110	--	--	--	90		213	--	30	--	5,450
	36	280	410	--	70	490	160	--	319	--		--	--	--	1,597	7,710
	37	--	--	--	400	--	--	--	--	110		--	--	--	658	2,120
Assembler-B Electro-Mechanical	34	--	--	--	--	--	--	--	--	--		--	--	--	--	--
	35	--	360	60	1[illegible]	110	--	248	1,241	400		250	--	1,350	1,655	12,590
	36	120	1,200	--	--	--	--	--	--	50		100	--	--	1,642	7,000
	37	--	170	--	170	--	--	--	--	--		--	250	--	603	5,070
Assembler-A Machine	34	--	--	--	--	--	--	--	--	--		--	--	--	--	--
	35	1,100	2,070	590	390	510	90	2,634	3,601	1,780		1,780	--	330	2,205	40,910
	36	150	780	--	--	--	--	937	--	870		70	--	--	248	6,440
	37	--	--	50	50	--	--	--	--	--		--	--	--	630	3,320

Table 8-8: OPERATIVE EMPLOYMENT BY REGION FOR SELECTED OPERATIVE CLASSES, 1977

OCCUPATION	SIC	NJ	NY	PA	GA	NC	TN	IN	IL	MI	OH	WI	TX	MO	CA	National
Assembler-B	34	--	--	--	--	--	--	--	--	--		--	--	--	--	--
Machine	35	590	1,810	160	180	620	120	395	2,171	680		2,115	--	330	1,852	24,010
	36	190	890	--	--	--	840	--	--	60		55	--	450	490	10,340
	37	--	120	00	00	00	00	695	--	200		145	--	--	781	7,270
Aircraft	34	--	--	--	--	--	--	--	--	--		--	--	--	--	--
Structure &	35	--	--	--	--	--	--	--	--	--		--	--	--	--	--
Surface	36	--	--	--	--	--	--	--	--	--		--	--	--	--	--
Assembler B	37	--	1,330	--	370	--	--	--	--	--		--	640	--	5,242	18,980
Conveyor	34	--	140	--	--	--	50	62	62	130		105	--	60	--	1,840
Operator	35	--	40	--	--	--	240	--	--	60		195	--	--	93	1,690
& Tender	36	60	160	--	--	--	240	1,838	--	--		225	--	170	40	7,350
	37	--	--	--	--	--	--	124	--	3,700		450	--	1,400	--	7,190
Coil Winder	34	--	--	--	--	--	--	--	--	--		--	--	--	--	--
	35	--	300	40	30	--	--	--	116	100		100	--	--	85	2,210
	36	1,390	1,540	--	300	1,0[illegible]	550	1,510	2,917	1,260		1,060	--	590	1,715	24,360
	37	--	--	--	--	--	--	--	--	--		--	--	--	--	--
Die Casting	34	--	570	--	--	--	110	34	--	270		--	--	--	183	1,490
Machine Oper-	35	--	230	--	--	--	--	--	--	30		--	--	160	28	1,670
ator &/or Die	36	--	140	--	30	60	--	535	--	180		95	--	170	199	3,370
Casting Setter	37	--	--	--	--	--	--	--	--	170		--	--	--	263	--
Die Setter	34	--	160	40	--	20	--	86	197	310		60	--	30	154	1,880
	35	--	--	--	50	--	--	--	--	140		--	--	--	28	--
	36	50	--	--	--	--	--	--	124	30		--	--	20	72	--
	37	--	880	--	--	--	--	--	--	50		--	--	--	82	--
Die Sinker	34	--	190	--	--	--	--	--	153	70		85	--	--	44	1,210
	35	--	--	--	--	--	--	--	152	150		--	--	--	92	--
	36	--	--	--	--	--	--	--	--	--		--	--	--	--	--
	37	--	--	--	--	--	--	57	--	90		--	--	--	51	--
Dip Plater	34	150	400	--	--	30	--	109	417	1[illegible]		105	--	110	381	4,120
	35	--	--	--	--	--	--	--	17	30		35	--	--	28	--
	36	--	60	--	--	--	--	--	--	50		115	--	90	442	3,660
	37	--	--	--	--	--	--	--	--	20		10	50	--	85	--
Drill Press	34	840	1,770	320	80	310	200	620	2,802	1,430		975	440	200	1,588	22,180
&/or Boring	35	1,560	2,530	480	360	1,150	500	2,631	7,977	4,810		3,05[illegible]	350	1,190	2,861	50,350
Machine	36	610	980	--	60	80	200	622	749	630		710	--	420	978	11,710
Operator	37	--	840	160	70	60	--	2,932	665	7,310		695	280	[illegible]	1,260	19,810

OCCUPATION	SIC	NJ	NY	PA	GA	NC	TN	IN	IL	MI	OH	WI	TX	MO	CA	National
Electro-plater	34	620	1,010	100	270	190	310	576	1,357	130		480	40	190	2,016	14,570
	35	--	120	--	--	--	--	194	216	110		180	90	30	195	1,820
	36	210	450	--	--	100	--	248	567	60		110	--	250	1,175	8,720
	37	--	40	--	--	--	--	112	--	350		--	110	--	291	2,240
Filer, Grinder, Buffer, Chipper, Cleaner, &/or Polisher	34	830	2,100	290	200	280	--	664	2,105	1,830		625	100	320	2,737	25,400
	35	560	1,600	230	320	390	270	1,015	2,139	1,400		1,080	--	430	1,621	21,970
	36	170	340	--	--	80	--	351	--	220		120	--	--	630	6,480
	37	--	570	140	190	120	--	1,268	--	4,120		265	610	220	2,917	23,510
Forging Press Operator	34	100	300	30	--	--	--	258	183	350		95	40	20	288	4,510
	35	--	--	30	--	--	--	--	--	20		65	--	--	174	--
	36	--	--	--	--	--	--	--	--	--		--	--	--	--	--
	37	--	--	--	--	--	--	238	--	430		--	--	--	98	1,990
Forging &/or Straightening Roll Operator	34	--	100	--	--	--	--	79	--	10		--	--	--	53	1,000
	35	--	--	--	--	--	--	--	--	--		--	--	--	--	--
	36	--	--	--	--	--	--	--	--	--		--	--	--	--	--
	37	--	--	--	--	--	--	--	--	--		--	--	--	--	--
Gear Cutting, Gear Grinding &/or Shaping Machine Operator	34	--	--	--	--	--	--	--	--	--		--	--	--	--	--
	35	--	210	60	50	170	--	352	1,532	350		350	--	100	212	6,210
	36	40	90	--	--	--	--	64	--	--		140	--	--	144	1,260
	37	--	130	--	--	--	--	--	--	1,040		330	--	--	142	3,600
Grinding &/or Abrading Machine Operator	34	670	1,700	330	280	300	60	784	1,734	1,490		710	230	160	1,879	21,450
	35	1,680	3,710	820	420	480	300	1,761	5,361	5,770		2,520	280	550	4,099	49,410
	36	340	500	--	--	20	60	379	237	280		200	--	140	500	6,330
	37	--	1,320	20	90	150	--	2,774	572	5,460		240	390	110	1,399	19,900
Heat Treater Annealers &/or Temperers	34	50	220	130	--	40	--	213	804	180		105	--	20	156	4,210
	35	110	290	90	--	90	--	280	1,187	340		265	--	60	109	4,920
	36	--	80	--	--	20	--	123	82	50		--	--	80	67	1,480
	37	--	240	--	--	--	--	839	--	1,370		140	70	--	191	4,160
Helper, Trades	34	970	890	110	420	320	-	167	1,284	1,050		215	260	--	1,549	21,370
	35	180	340	100	130	--	90	146	785	250		365	--	190	728	7,110
	36	80	260	--	--	110	--	--	1,598	230		425	--	40	206	2,280
	37	--	340	00	150	200	--	98	75	240		80	720	--	1,169	8,230
Inspectors	34	1,230	1,460	340	250	620	1,640	1,452	3,821	3,990		1,470	360	680	2,973	37,660
	35	1,420	3,220	550	280	780	890	2,434	4,992	3,600		2,530	550	1,440	3,945	50,370
	36	2,250	4,000	--	400	1,420	1,040	5,421	5,306	1,430		1,380	--	1,980	7,129	64,280
	37	--	--	50	1,090	--	--	--	2,640	20,080		1,780	1,670	1,710	7,382	76,270

OCCUPATION	SIC	NJ	NY	PA	GA	NC	TN	IN	IL	MI	OH	WI	TX	MO	CA	National
Laminators, Preforms	34	--	--	--	--	--	--	--	--	--		--	--	--	--	--
	35	--	--	--	--	--	--	--	--	--		--	--	--	--	--
	36	--	--	--	--	--	--	--	--	--		--	--	--	--	--
	37	--	510	--	220	290	--	415	189	300		220	1,270	--	1,548	10,160
Lathe &/or Turning Machine Operator, Metal	34	1,100	1,710	360	60	--	120	980	2,642	2,160		1,215	1,180	370	2,492	28,930
	35	2,440	4,350	1,090	800	1,210	470	3,014	7,390	4,590		3,925	490	1,250	4,550	69,040
	36	400	1,420	--	60	100	120	562	836	580		595	--	340	995	10,810
	37	--	860	150	90	70	--	3,323	615	4,620		960	780	--	1,612	21,480
Lay-out Marker, Metal	34	490	580	220	150	180	--	203	408	410		165	--	260	618	9,070
	35	120	240	50	120	70	80	210	229	320		505	--	80	199	4,850
	36	40	100	--	--	--	--	--	--	30		10	--	80	137	--
	37	--	100	--	--	--	--	110	--	240		90	150	40	675	2,760
Mixer &/or Blender Chemicals & Chemical Products	34	--	--	--	--	--	--	--	--	--		--	--	--	--	--
	35	--	--	--	--	--	--	--	--	--		--	--	--	--	--
	36	--	180	--	60	20	60	361	132	30		90	--	40	--	2,700
	37	--	--	--	--	--	--	--	--	--		--	--	--	--	--
Machinist	34	1,170	1,020	370	200	440	590	567	2,045	1,030		680	790	390	3,035	23,540
	35	1,450	2,960	770	610	820	900	1,697	3,885	2,470		1,735	310	730	5,078	58,560
	36	640	980	--	60	350	--	--	1,598	230		425	--	--	2,524	14,090
	37	--	--	120	340	--	--	218	49	670		140	550	--	5,619	16,560
Machine Tool Operator--Combination	34	1,000	1,930	350	250	410	--	738	2,754	2,470		990	360	460	1,812	25,760
	35	2,090	3,920	750	590	1,220	720	2,775	3,829	7,380		2,695	40	810	5,850	70,580
	36	1,510	1,070	--	200	430	--	1,601	1,370	480		580	--	--	1,428	14,340
	37	--	--	--	180	--	--	2,470	769	6,730		1,130	700	--	2,641	32,070
Machine Tool Operator--Numerical Control	34	150	240	40	--	90	--	165	352	220		115	60	140	281	3,970
	35	850	1,430	500	60	510	150	787	2,727	1,810		1,915	50	430	2,290	26,690
	36	100	410	--	--	60	--	--	169	20		190	--	170	497	5,570
	37	--	770	--	--	--	--	184	220	290		160	330	--	1,120	5,670
Machine Tool Operator--Tool Room	34	180	340	130	--	50	--	184	392	850		175	90	50	308	5,040
	35	360	560	50	30	90	90	852	1,748	1,860		850	120	230	306	11,610
	36	100	510	--	--	100	--	692	199	140		175	--	100	363	5,080
	37	--	--	60	40	--	--	1,345	200	4,400		440	110	--	443	11,680
Milling &/or Planing Machine Operator	34	120	550	100	--	--	130	196	632	250		135	110	50	418	5,510
	35	1,160	2,740	750	370	550	260	908	3,532	3,720		1,855	140	430	2,306	36,940
	36	200	470	--	--	--	--	162	--	90		160	--	--	372	3,470
	37	--	970	110	--	70	--	939	--	1,920		305	650	--	1,597	12,980

OCCUPATION	SIC	NJ	NY	PA	GA	NC	TN	IN	IL	MI	OH	WI	TX	MO	CA	National
Millwrights	34	100	320	250	40	30	--	409	744	1,240		200	--	160	248	7,670
	35	190	330	120	30	30	230	374	1,308	690		385	--	190	229	5,180
	36	100	280	--	--	120	150	581	166	180		85	--	120	32	3,810
	37	--	680	--	100	--	--	966	325	4,700		470	180	330	221	11,410
Machine Tool Setter	34	170	580	50	100	120	--	360	708	740		380	70	90	555	8,780
	35	910	1,250	70	110	340	170	316	1,572	1,250		670	60	290	776	15,670
	36	450	790	--	--	160	80	473	466	140		130	--	130	228	6,690
	37	--	1,420	--	40	--	--	1,532	--	7,050		195	--	--	644	--
Painters, Maintenance	34	70	50	30	60	--	--	75	53	--		25	--	20	60	1,320
	35	60	140	20	--	20	--	90	245	170		95	--	30	79	1,770
	36	--	80	--	--	--	--	93	--	30		30	--	--	144	1,390
	37	--	230	--	50	--	--	89	89	460		460	140	60	457	2,730
Order Filler	34	180	210	60	--	40	100	311	700	--		215	60	70	403	5,790
	35	160	400	30	--	160	--	926	1,196	--		370	--	130	317	1,340
	36	410	310	--	--	110	--	820	--	--		695	--	240	518	6,450
	37	--	90	--	--	--	--	306	--	--		25	70	240	301	4,280
Painters, Production	34	800	1,340	230	320	290	330	919	1,326	1,460		745	70	350	1,751	19,830
	35	460	640	60	200	300	300	453	1,611	800		925	90	340	810	14,020
	36	410	750	--	140	210	330	714	817	200		405	--	240	966	10,000
	37	--	730	30	650	180	--	870	1,288	4,350		795	1,160	890	3,143	30,530
Plater Helper	34	590	1,410	70	130	190	250	705	1,203	705		570	--	160	1,744	14,510
	35	--	--	--	--	--	--	--	44	30		135	--	30	--	--
	36	--	200	--	--	120	250	59	--	--		75	--	90	142	3,920
	37	--	--	--	--	--	--	--	--	100		--	70	--	286	--
Power Brake &/or Bending Machine Operator, Metal	34	250	1,330	160	220	400	140	904	1,549	950		490	290	370	1,344	17,350
	35	--	420	20	120	160	310	281	1,213	220		500	--	310	339	7,260
	36	70	190	--	150	80	590	--	172	30		125	--	160	247	2,670
	37	--	220	--	--	--	--	430	--	--		60	190	--	666	5,960
Production Packager, Hand or Machine	34	1,510	2,150	200	410	230	490	1,391	2,630	1,400		1,585	210	650	2,180	26,300
	35	200	640	70	30	70	--	592	634	350		535	--	170	446	7,400
	36	1,200	1,770	--	320	280	490	1,792	1,619	410		690	--	570	1,112	16,550
	37	--	690	--	120	--	--	131	271	660		125	150	--	494	5,230
Punch Press Operator, Metal	34	4,080	3,800	840	1,740	480	1,180	4,399	8,825	19,020		2,665	60	1,380	4,440	84,480
	35	560	1,200	80	320	310	720	1,420	4,362	1,590		1,280	250	690	1,601	22,110
	36	810	1,620	--	540	470	1,180	1,811	2,548	670		885	--	950	1,040	23,640
	37	--	1,600	--	--	--	--	2,583	--	9,840		1,675	230	300	719	29,660

OCCUPATION	SIC	NJ	NY	PA	GA	NC	TN	IN	IL	MI	OH	WI	TX	MO	CA	National
Punch Press Setter, Metal	34	270	350	50	70	50	--	527	791	1,020		300	--	270	424	7,540
	35	180	120	--	--	50	180	138	379	130		70	--	50	144	2,930
	36	60	210	--	540	60	90	159	367	110		140	--	120	170	2,950
	37	--	140	--	--	--	--	129	--	730		240	--	--	115	--
Rigger	34	--	--	80	30	--	--	113	92	150		20	--	40	24	1,720
	35	--	180	50	--	--	--	47	176	100		315	--	--	13	1,710
	36	--	--	--	--	--	--	--	--	--		--	--	--	--	--
	37	--	100	--	30	--	--	75	--	90		90	140	--	458	3,520
Riveter, Light	34	90	210	--	--	--	--	210	130	90		90	--	60	146	1,890
	35	-	--	--	--	--	--	60	--	30		30	--	--	--	2,410
	36	--	--	--	--	--	--	78	727	60		245	--	200	49	2,410
	37	--	220	--	260	--	--	559	--	220		--	80	--	272	2,380
Roll Forming Machine Operator	34	130	190	140	70	--	--	325	540	280		230	--	50	321	4,320
	35	--	--	--	--	--	--	--	--	--		--	--	--	--	--
	36	--	--	--	--	--	--	--	--	--		--	--	--	--	--
	37	--	--	--	--	--	--	--	--	--		--	--	--	--	--
Riveter, Heavy	34	--	50	--	--	--	--	--	--	--		--	--	--	21	--
	35	--	--	--	--	--	--	--	--	--		25	--	--	11	--
	36	--	--	--	--	--	--	--	--	--		--	--	--	--	--
	37	--	--	--	60	--	--	299	--	390		--	70	--	110	1,320
Sandblaster &/or Shot Blaster	34	60	270	110	40	50	--	153	194	260		115	--	40	256	3,310
	35	--	200	30	40	70	--	96	376	150		170	--	20	95	2,980
	36	--	--	--	--	--	--	--	--	--		--	--	--	--	--
	37	--	--	--	--	--	--	342	--	--		--	--	--	--	--
Shear &/or Slitter Operator, Metal	34	550	850	310	180	180	60	698	1,136	950		520	--	360	1,155	13,160
	35	100	180	30	30	80	140	223	717	150		405	--	170	197	4,290
	36	100	150	--	70	--	60	102	210	60		90	--	130	130	1,940
	37	--	80	--	--	--	--	342	--	260		55	110	30	170	3,060
Sheet Metal Worker	34	1,370	1,150	150	520	400	--	474	739	1,090		280	--	320	2,738	20,710
	35	690	1,240	110	460	380	--	467	1,359	960		635	--	--	1,551	20,730
	36	170	650	--	--	100	--	258	284	130		220	--	--	1,024	6,900
	37	--	900	20	180	50	--	449	96	1,700		355	1,370	190	2,878	16,610
Tester	34	340	440	140	110	--	720	466	378	290		580	60	180	366	6,760
	35	400	530	210	60	190	--	456	913	620		495	--	160	1,028	8,150
	36	1,900	1,370	--	--	990	1,720	1,026	2,518	1,170		860	--	580	2,682	26,540
	37	--	630	--	60	--	--	1,144	221	2,220		75	220	130	725	10,020

176

193

194

OCCUPATION	SIC	NJ	NY	PA	GA	NC	TN	IN	IL	MI	OH	WI	TX	MO	CA	National
Tool & Die Makers	34	1,310	1,440	310	120	270	260	1,284	3,052	6,590		800	90	310	1,491	29,750
	35	1,870	4,030	400	280	580	--	2,992	5,478	8,640		2,595	--	1,020	2,860	54,960
	36	890	1,270	--	100	--	260	1,824	1,452	550		415	--	380	704	17,030
	37	--	880	--	--	--	--	1,292	547	7,230		605	500	180	1,530	20,160
Welder &/or Flame-cutter--A	34	670	1,120	480	260	440	--	488	930	1,160		660	--	550	1,681	24,600
	35	650	1,560	360	600	800	540	1,196	2,752	1,110		3,460	440	670	2,991	1,560
	36	160	390	--	270	160	--	278	318	100		290	--	--	478	4,410
	37	--	1,010	20	320	--	--	376	113	1,680		650	1,900	90	2,790	18,940
Welder &/or Flame-cutter--B	34	1,260	2,540	1,000	870	880	--	1,656	2,064	6,580		1,120	320	950	2,734	46,780
	35	710	1,540	470	680	760	740	1,245	5,932	2,850		2,610	640	730	3,030	1,540
	36	130	470	--	--	--	--	702	182	130		165	--	150	478	5,480
	37	--	1,450	400	1,090	320	--	2,368	1,825	9,000		980	2,810	2,250	4,580	54,380
Welder &/or Flame-cutter--C	34	650	790	320	360	250	--	698	1,412	2,590		905	180	390	1,342	17,740
	35	220	420	120	510	310	800	671	3,015	1,030		1,135	250	340	1,058	420
	36	270	440	--	100	190	--	335	390	630		405	--	540	464	6,210
	37	--	190	--	410	--	--	1,194	1,474	3,150		2,670	720	460	1,343	28,740
Wirer, Electronic	34	--	--	--	--	--	--	--	--	--		--	--	--	--	--
	35	--	--	--	--	--	--	--	--	--		--	--	--	--	--
	36	2,000	2,600	--	--	--	390	1,061	3,854	220		445	--	--	1,359	22,940
	37	--	--	--	--	--	--	--	--	--		--	--	--	--	--
Unclassified Skilled Craft & Kindred Workers	34	680	520	650	170	880	--[D]	778	2,404	2,150		765	1,260	310	1,682	25,200
	35	450	1,950	170	100	240	--	338	3,204	2,040		1,410	800	250	771	33,270
	36	1,010	1,450	--	250	1,490	--	958	1,574	550		430	--	370	1,581	21,780
	37	--	770	510	860	630	--	1,980	721	5,530		490	1,120	290	4,886	25,430
Unclassified Semi-skilled Workers	34	2,480	1,320	990	640	2,720	10,250	2,075	5,915	3,700		2,665	1,050	1,190	6,108	64,620
	35	2,130	3,820	440	400	1,230	4,340	3,083	7,504	4,010		3,185	1,170	1,140	3,548	62,670
	36	4,130	4,510	--	1,030	1,910	8,450	6,952	13,282	1,490		2,395	--	2,050	7,035	89,940
	37	--	4,300	1,520	4,180	880	--	3,915	2,456	31,140		2,800	2,270	5,340	8,179	106,660
Total Workers enumerated above (34-37)																
Total Production Workers[E]	34	45,160	60,270	16,610	15,240	17,410	65,000	49,270	98,915	114,690		43,270	11,210	22,590	93,570	1,191,810
	35	38,660	77,640	14,080	13,000	24,120	22,220	54,272	142,166	96,740		74,085	11,370	24,400	90,975	1,368,450
	36	49,670	77,860	--	11,400	30,340	31,250	89,404	97,160	31,770		35,725	--	32,920	109,166	1,201,160
	37	--	54,480	4,470	23,940	7,210	--	80,797	26,930	293,770		35,405	36,810	32,960	132,494	1,330,380
Metalworking Total		133,490	270,250	35,160	63,580	79,080	78,470	273,743	365,171	536,970		188,485	59,390	112,870	426,205	5,091,800
Total Production Workers, All Manufacturing[F]		490,000	958,000	934,000	376,000	611,000	376,000	522,000	858,000	789,000		381,000	601,000	299,000	1,143,000	13,963,950
% of Production Workers in Metalworking		27.2	28.2	3.8	16.9	12.9	20.9	52.4	42.6	68.1		49.5	9.9	37.7	37.3	36.5

177

FOOTNOTES TO OCCUPATIONAL EMPLOYMENT BY REGION FOR SELECTED METALWORKING OPERATIVE CLASSES, 1977

[A]State employment figures taken from the Occupational Employment Statistics report from the state for manufacturing employment, 1977. States that list only a subset of metalworking industries are noted in Table "Coverage of Occupational Employment Statistics Report for Metalworking Employment, 1977." National totals are taken from "Occupational Employment in Manufacturing Industries, 1977," BLS Bulletin 2057.

[B]Regions correspond to Standard Bureau of Labor Statistics divisions. Only a subset of states in each region is shown.

[C]Either there is no listing for this industry, or there is no listing for this particular occupational title in the industry.

[D]For Tennessee, unclassified workers are not broken down skill. They are assigned to unclassified semi-skilled workers.

[E]Figure taken from listing for "Production, Maintenance, Construction Repair, Material Handling and Power Plant Occupations, Total," from both statewide reports and national summary. This includes all production workers, including those enumerated above.

[F]Figures taken from Statistical Abstract, 1980, Table 1445, "Manufacturing Summary by States: 1967."

Table 8-9: ADDRESSES OF STATE RESEARCH AND ANALYSIS OFFICES

ALABAMA

Research and Statistics
Department of Industrial Relations
Industrial Relations Building
649 Monroe Street
Montgomery, Alabama 36103
205-832-5263

ALASKA

Research and Analysis
Employment Security Division
Department of Labor
Post Office Box 3-7000*
State Office Building, Ninth Floor
Juneau, Alaska 99811
907-465-4501

ARIZONA

Research and Analysis
Dept. of Economic Security
1400 West Washington
Post Office Box 6123*
Phoenix, Arizona 85005
602-271-3616

ARKANSAS

Research and Statistics
Employment Security Division
Post Office Box 2981*
State Capitol Mall
Little Rock, Arkansas 72203
501-371-1541

CALIFORNIA

Employment Data and Research Division
Employment Development Dept.
800 Capitol Mall
Sacramento, California 95814
916-445-4434

COLORADO

Research and Analysis
Division of Employment
Dept. of Labor and Employment
251 East 12th Avenue
Denver, Colorado 80203
303-893-2400, ext. 431

CONNECTICUT

Research and Information
Connecticut Employment Security Division
200 Folly Brook Boulevard
Wethersfield, Connecticut 06115
203-566-2120

DELAWARE

Office of Research, Planning and Evaluation
Department of Labor
205 West Fourteenth Street
Wilmington, Delaware 19899
302-571-2930

DISTRICT OF COLUMBIA

Division of Manpower Reports and Analysis
Office of Adm. & Management Serv.
D. C. Department of Manpower
605 G Street, N. W.
Washington, D. C. 20001
202-724-2413

FLORIDA

Research and Statistics
Division of Employment Security
Department of Commerce
Caldwell Building
Tallahassee, Florida 32304
904-488-1048

GEORGIA

Information Systems
Employment Security Agency
Department of Labor
254 Washington Street, S. W.
Atlanta, Georgia 30334
404-656-3177

HAWAII

Research and Statistics
Department of Labor and Industrial Relations
825 Mililani Street
Honolulu, Hawaii 96813
808-548-7639

IDAHO

Research and Analysis
Department of Employment
Post Office Box 35*
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*Use instead of street address for mailing purposes.

1 Taken from "Jobs in the Private Sector: Use of Labor Market Information," U.S. Department of Labor, Employment and Training Administration Division of Labor Information, Monograph No. 2, October, 1980.

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*Use instead of street address for mailing purposes.

Table 8-10: DEFINITION OF WORKER COMPLEXITY LEVELS

0. Setting Up: Adjusting machines or equipment by replacing or altering tools, jigs, fixtures, and attachments to prepare them to perform their functions, change their performance or restore their proper functioning if they break down. Workers who set-up one or a number of machines are included here.

1. Precision Working: Using body members and/or tools or work aids to work, move, guide, or place objects or materials in situations where ultimate responsibility for the attainment of standards occurs and selection of appropriate tools, objects, or materials, and the adjustment of the tool to the task require exercise of considerable judgement.

2. Operating-Controlling: Starting, stopping, controlling, and adjusting the progress of machines or equipment. Operating machines involves setting up and adjusting the machine or material(s) as the work progresses. Controlling involves observing gages, dials, etc., and turning valves and other devices to regulate factors such as temperature, pressure, flow of liquids, speed of pumps, and reactions of materials.

3. Driving-Operating: Starting, stopping, and controlling the actions of machines or equipment for which a course must be steered, or which must be guided, in order to fabricate, process, and/or move things or people. Involves such activities as observing gages and dials; estimating distances and determining speed and direction of other objects; turning cranks and wheels; pushing or pulling gears lifts or levers. Includes such machines as cranes, conveyor systems, tractors, furnace charging machines, paving machines and hoisting machines. Excludes manually powered machines, such as handtrucks and dollies, and power assisted machines, such as electric wheelbarrows and handtrucks.

4. Manipulating: Using body members, tools, or special devices to work, move, guide, or place objects or materials. Involves some latitude for judgement with regard to precision attained and selecting appropriate tool, object, or material.

5. Tending: Staring, stopping, and observing the functioning of machines and equipment. Involves adjusting materials or controls of the machine such as changing guides, adjusting timers and temperature gages. Turning valves to allow flow of materials, and flipping switches in response to lights.

6. Feeding-Offbearing: Inserting, throwing, dumping, or placing materials in or removing them from machines or equipment which are automatic or tended or operated by other workers.

7. Handling: Using body members, handtools, and/or special devices to work, move or carry objects or materials. Involves little or no latitude for judgement with regard to attainment of standards or in selecting appropriate tool, object, or material.

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*Source: Dictionary of Occupational Titles, 4th Edition, 1977. U.S. Department of Labor, pp. 1369-1371

Table 8-11: QUESTIONNAIRE

CLASSIFICATION OF MACHINE OPERATIVES

JOB COMPLEXITY LEVEL	DESCRIPTION OF WORKER COMPLEXITY LEVEL	# OF WORKERS IN COMPLEXITY LEVEL	% OF THESE JOBS THAT COULD BE PERFORMED WITH A ROBOT*
0 (Highest)	Setting Up		
1	Precision Working		
2	Operating-Controlling		
3	Driving-Operating		
4	Manipulating		
5	Tending		
6	Feeding-Offbearing		
7	Handling		

* A robot with rudimentary sensory capabilities

Table 8-12: SURVEY: CLASSIFICATION OF SEMI- SKILLED OPERATIVES

1. Industrial classification of establishment(4 digit SIC if known)._____

2. Total number of production workers in plant._____

3. Percentage breakdown of total production by batch size:

_____ Custom (1-100 units/year)
_____ Small batch (101-1000)
_____ Large batch (1000-10,000)
_____ Mass (over 10,000)

Job Classification	#Of employees in job classification (optional)	% Of these jobs which could be done by a Level 1 robot	Level 2
Inspectors			
Testers			
Assemblers			
Casters			
Coilers/Winders			
Conveyor operators			
Packagers			
Order Fillers			
Machine or Machine Tool operators, non-numerical control			
Machine or Machine Tool operators, Numerical-control			
Machine or Machine Tool setter			
Welder/Flamecutter			
Filers, Grinders, Buffers, & Polishers			

Job Classification	# Of employees in job classification	% Of these jobs which could be done by a Level 1 robot	Level 2
Painter			
Mixer			
Sandblaster/shotblaster			
Millwright			
Oiler			
Rigger			
Pourer			
Kiln or Furnace operator			
Tenders			
Trades helper			
Tool and Die Maker			
Electro-Plater			
Dip Plater			
Lay Out Marker			
Etcher/Engraver			
Other operatives and semi-skilled workers			

IV. APPENDIX D TECHNOLOGY INITIATED CHANGE MODEL

A model has been constructed to assess first order implications of new technology for the labor force. Hopefully, this sort of exercise will indicate possible areas of concern for unions in their effort to protect members from any adverse effects caused by the introduction of robotics. The outcome of an event such as the introduction of robots in some new application depends on values assigned to variables contained within the model. For example, the labor/robot replacement ratio and the introduction rate of robots determine the number of workers affected in a time period. Current values for accession, separation, and rate of retention determine the number of openings to absorb a part or all of the affected group. The model displays outcome classes and sizes based on the population's input values. A more detailed description of the model appears below.

IV.1 PROBLEMS AND LIMITATIONS WITH EXISTING DATA

While it is true that BLS and DOL statistical publications provide information on production worker populations in SIC-coded industries, and that states provide population figures for operative classes, there is difficulty in obtaining this information as it applies directly to unions, the desired focus point. In performing a simulation of the TIC Model, some extrapolation or analogy construction is necessary. For example, with a knowledge of the percentage of a given operative class in an industry-wide work force (nationally, in a state or an SMSA) and the knowledge of a particular union's membership as a percentage of the same industry-wide work force, an approximation for the number of union members in the particular operative class can be estimated.

Values for introduction rate and replacement ratio are not known for specific operative classes. As a further source of confusion, operative classes as defined by state occupational employment surveys need not correspond to operative classes as defined by industry or by unions; and it is these industry/union defined classes that are to be scrutinized when the technological innovations are introduced. It is assumed, however, that this information can be obtained by, or is already in the possession of the particular industry/employer or union which would apply the model.

Retention proportions for the calculation of number of workers retrained to work with the newly introduced devices is currently not specified.

Information on attrition and job openings exists for four digit SIC-coded industries. These data are compiled by the BLS. The broad heading of separations is given, and it includes any termination: quit, lay off, death, discharge, retirement, permanent disability. As

subsets of separations, quits and lay offs are tabulated. Again, this information is not indexed to unions in any way. In addition, state occupational employment tabulations offer (projected) figures for accession and attrition.

IV.2 FUNCTIONAL OVERVIEW

The elements of the model are as follows:

1. A worker population--this can be a particular firm, industry, the membership of a local or national union, or the population of a state or region. It is assumed that the worker population is composed of many semi-skilled job classes. Some typical job classes are lathe operator, drill press operator, welder, machinist, and assembler.

2. Jobs lost due to robotics introduction are determined by the rate of replacement of workers by robots, and by the number of robots to be introduced in the particular case being considered.

3. Robotics introduction displaces individuals; these individuals can continue to work as a result of the existing mechanisms of separation and retention, or they are laid off as a result of robotics introduction.

    - Openings in a job class occur because of separation, which includes openings due to quits, lay off (exclusive of robotics introduction) and the catch-all category "other". "Other" includes openings due to all forms of retirement, discharge, disability and death of workers. Under separation, all the elements of the division "other" and the division "quit" are commonly referred to as attrition.

    - Openings in a job class also occur because of retention, which includes retraining for jobs with the newly introduced technology, and the mechanism of accession. Accession includes new hires due to growth and rehires.

    - Lay off, for those who are unable to take advantage of openings due to separation and retention, can be temporary or permanent.

Worker Population	Job Class	Replacement Ratio	Introduction Rate	Displaced Workers
W	J	R N	D	

$J \times R \times N = D$

S- Separation
- Quit
- Lay off (exclusive of robotics intro.)
- Other (including retirement)

Displacement

Retention
- A- Accession
- R- Retraining

L- Lay off (due specifically to robotics intro.)

J x separation rate = S- openings due to separation

J x accession rate = A- openings due to separation

D x rate of retention (due to retraining) = R- retraining rate

D - (S + A + R) = L

The fundamental need for detailed job classification follows from the realization that there are unique values for the scope of an application and the replacement ratio for particular job categories. Current examples of robot application in the automotive industry include spot welding and spray painting. These are quite different tasks. Clearly, the replacement ratio -- the number of workers or man-hours displaced by the introduction of a robot-- need not be the same for both classes.

IV.3 MODEL SIMULATION

Even though it was not possible to determine completely dependable data in order to produce a quantitative analysis, it was decided to illustrate the model with estimates of quantitative information, and hypothetical situations. Values for worker population, job class size, replacement ratio, retention ratio and introduction rate expressed as a numerical value for a discrete instance were obtained. The calculation for number of displaced could be performed; outcome branches could be evaluated. Separation rate could be broken down into quits, lay-offs and other (which includes all forms of retirement.) Retention could be broken down into retraining and accession. A final path would be lay-off due to robotics introduction.

The population was selected from the state of Illinois for the purposes of the simulation

because as of 1975, Illinois had the highest number of manufacturing jobs in SIC 35, machinery (except electrical), of any of the fifty states. Since specific data for job class sizes within particular unions is currently unavailable, a simulation outcome cannot be generated for a specific union. It is suggested, though, that a simulation outcome for SIC 35 in Illinois will be relevant to the IAM, for example. This might be due to the fact that 17.7% of the IAM's total membership works in SIC 35 industries; 9.9% of the IAM's total membership works in Illinois. Likewise, a simulation outcome for SIC 37, transportation equipment, in Michigan, is expected to be of interest to the UAW.

Three job classes were selected arbitrarily: lathe and turning machine operators, punch-press operators, and welders and flamecutters. Two sets of figures for 1975 were available from the Illinois Occupational Employment Projection: for the entire industry-job class size, openings due to growth and separation; for SIC 35- job class size.

Table 8-13: ILLINOIS: AVERAGE ANNUAL JOB OPENINGS, DUE TO GROWTH AND SEPARATION, BY OCCUPATION 1976-1985

	number	growth	separation
Lathe and milling machine operators	467	204	263
Punch and stamp press ops.	835	341	493
Welders and flame cutters	1675	818	857

Illinois: Occupational Employment, Machinery (except Electrical), SIC 35

	employed (est.)
Lathe and milling machine operators	7360
Punch and stamping press operators	4362
Welders and flame cutters	11705

It can be assumed that dividing the job class size for a particular industry by the job class size for all manufacturing industries, results in a ratio representing the percentage of workers employed in a particular industry (W(pi)) This number (W(pi)) multiplied by the Illinois industry wide openings, the growth value (number of people expected to be taken into the industry), and the separation value(number of people expected to be dismissed from the company though not due to the introduction of robotics) produces respectively the number of openings, the growth value (A(pi)) and the separation value (S(pi)) for the particular industry. Openings in the particular industry equals the sum of the growth value and separation value in the particular industry.

Since values for Illinois industry wide accession and separation rates were not available,

Table 8-14: Total Employment in Illinois, by Occupation

	employed (est.)
Lathe and milling machine operators	8938
Punch and stamping press operators	17295
Welders and flame cutters	38959

Job Turnover Rates for SIC 35

Accession: 3.2% Separation:3.2%
new hire: 2.7% other: .5% quit: 1.6% lay-off: .6% other: 1%

national values for 1974 BLS data were used instead. This assumes that the Illinois turnover rates equal the national turnover rates.

Accession breaks down into "new hires" and "others". Similarly, separation divides into "quits", "lay offs", and "others"(including all forms of retirement).

Dividing the "new hires" by the Illinois accession rate (assuming Illinois values equal national values) determines the percentage of new people to be hired in Illinois. Multiplying this proportion by the A(pi) (growth value for the particular industry) produces the number of new hires in the particular industry (NH(pi)). This number subtracted from the A(pi) gives the number of people designated as "others" under the accession rate for the particular industry (AO(pi)). By similar calculations, "quits" divided by the separation rate (again assuming comparable U.S. and Illinois values) and multiplied by the S(pi) (separation value for the particular industry) equals the number of quits within the particular industry (Q(pi)); "lay offs" divided by the separation rate and multiplied by S(pi) equals lay offs for the particular industry (L(pi)); and "others" divided by the separation rate and multiplied by S(pi) equals others in the particular industry (SO(pi)).

Using Illinois lathe operators as an example, the calculations can be clarified.

1. **88983 persons work as lathe and milling machine operators; 7390 of these persons work in industries covered by SIC 35.**

$$\frac{7390}{8938} = W(pi)\ \text{(workers employed in a particular industry)}$$

W(pi) = 82%

2. **467 openings exist in the state wide industry**

(W(pi)*(openings) = (.82)(467) = 383 openings available for

lathe operators in SIC 35

3. **204 persons covered by total Illinois growth values**

(W(pi))(accession) = A(pi)
(.82)(204) = 167 persons classified as "new hires"
or "others"

4. **3.2% national accession rate comprised of 2.7% "new hires" and .5% "others"**

new hires
---------- (A(pi)) = NH(pi)
accession rate

2.7%
---- (167) = 141 new persons to be hired
3.2%

167-141 = 26 others (AO(pi))

5. **263 persons involved in total Illinois separation rates**

(W(pi))(separation value) = (S(pi))
(.82)(263) = 216 persons to be classified as "quits",
lay offs", or "others"

6. **3.2 separation rate comprised of 1.6% quits, .6% lay offs and 1% others**

quits
----------(S(pi)) = Q(pi)
separation rate

1.6%
----(216) = 108 persons to quit
3.2%

lay offs
----------(S(pi)) = L(pi)
separation rate

.6%
----(216) = 40 persons to be laid off
3.2%

others
----------(S(pi)) = SO(pi)
separation rate

1%
----(216) = 68 others including retirees
3.2%

The following chart based on data included in Table 8-12 summarizes the calculations for all three examples: lathe and milling machine operators; punch press operators; and welders and flamecutters in SIC 35.

SUMMARY OF CALCULATIONS

(S refers to statewide industries:
P refers to the particular industry in SIC 35)

Lathe and Milling Operators

Employment	Openings	Growth	Separation
S-8938	383	167	216
P-7390		NH(pi)-141	Q(pi)-108
W(pi)-82%		AO(pi)-26	L(pi)-40
			SO(pi)-68

Punch and Stamping Press Operators

Employment	Openings	Growth	Separation
S-17295	209	85	124
P-4362		NH(pi)-72	Q(pi)-62
W(pi)-25%		AO(pi)-13	L(pi)-23
			SO(pi)-39

Welders

Employment	Openings	Growth	Separation
S-38959	502	245	257
P-11705		NH(pi)-207	Q(pi)-128
W(pi)-30%		AO(pi)-38	L(pi)-48
			SO(pi)-81

Replacement Ratios and Retraining Factors

Trade publication accounts of robotics introduction at existing plants provides replacement ratios and retraining/retention percentages. For one reported case, eight robots replaced sixteen workers in a machining operation, giving an 8 to 16 or 1:2 replacement ratio. Six workers were retained to load and operate the robots providing a retraining/retention level of 6:16 or 37.5%. This example was used to estimate a replacement ratio for lathe operators.

In another case, used to estimate a replacement ratio for punch press operators, two robots replaced six workers in a drive-shaft machining and assembly cell; two workers were retained to operate the robots. This determines the replacement ratio of 2:6 (i.e. 1:3) and a retraining/retention level of 2:6 or 33%.

In the final example, 27 robots replaced 67 workers; seven workers were retained to

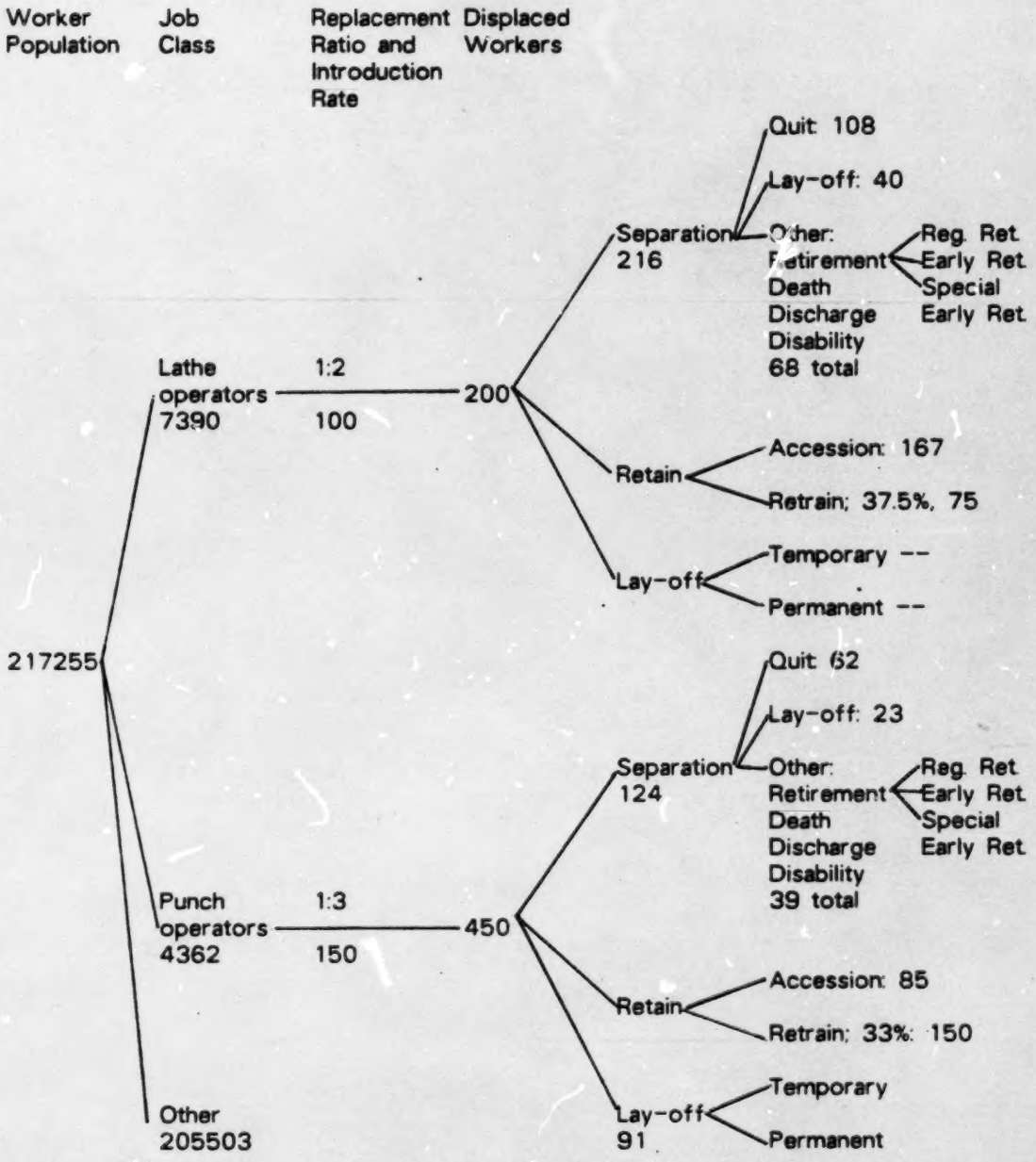
operate the new devices. This yields 2:5 replacement ratio and a 10.5% retraining/retention percentage.

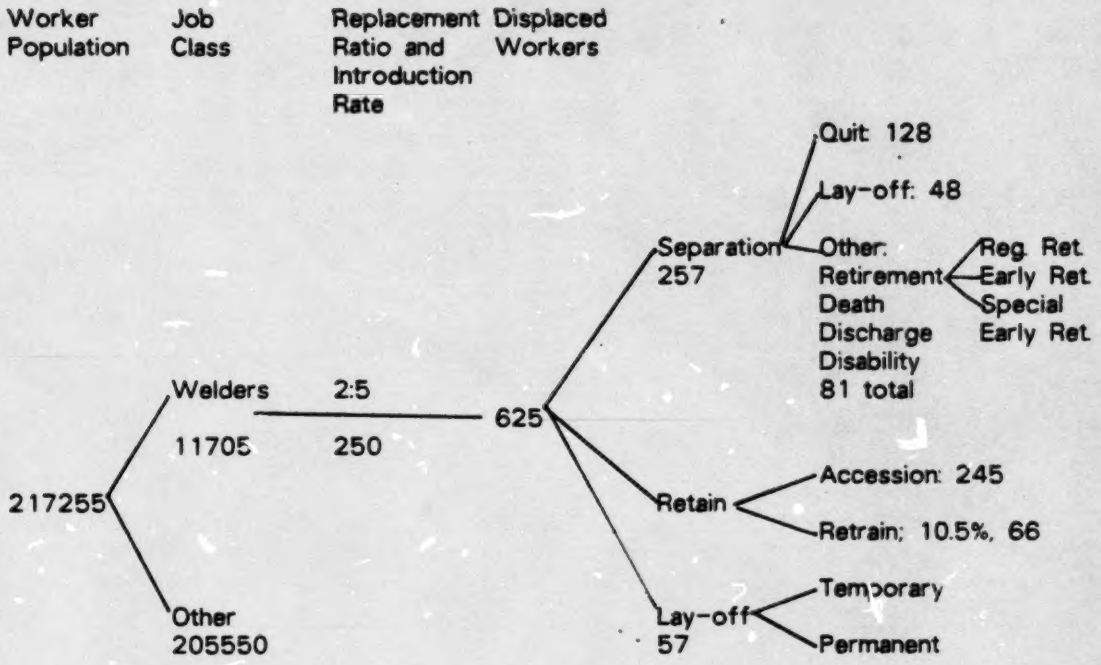
Illustrative Simulation Outcomes

The first set of simulations are performed for three job classes on a state-wide basis. It has been suggested that an examination of a simulation conducted on a statewide basis is of particular interest because it is the states that run welfare and unemployment compensation programs, and it is states that go to the federal government to obtain more money "when the well runs dry". The implication seemed to be that outcomes on a state population level of magnitude were the ones worth predicting.

On the other hand, it has been pointed out that the effects of the introduction of robotics will first manifest itself on the individual factory level. Consequently, simulations with single factory populations have been performed as well

Industry-wide Simulation





IV.4 INDUSTRY-WIDE SIMULATION RESULTS

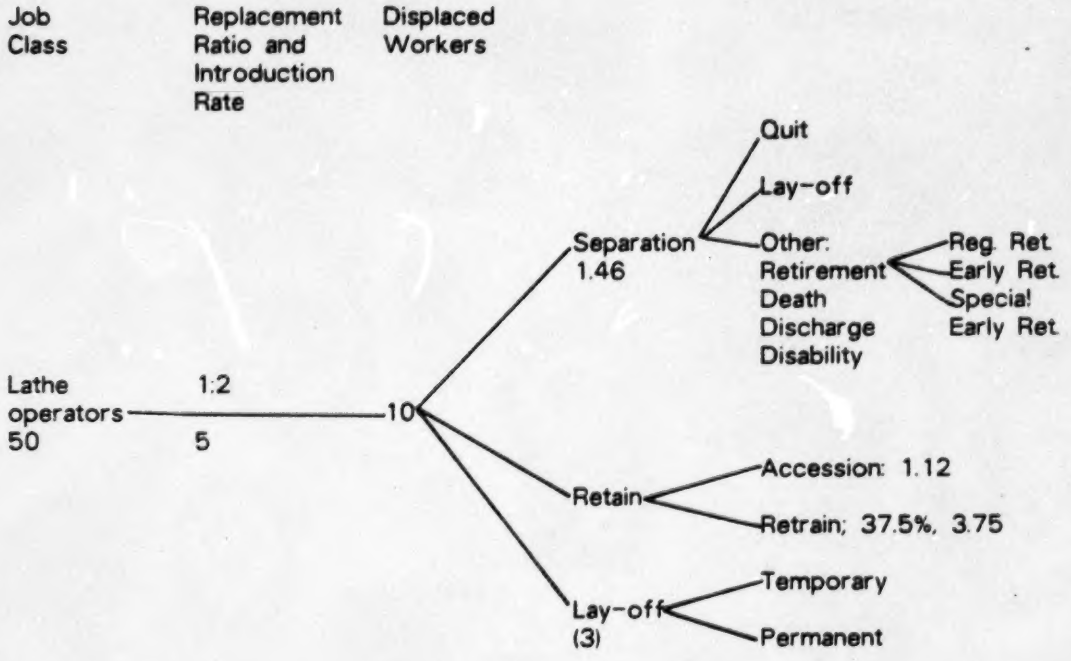
The introduction of robots results in a potential loss of 250 jobs for lathe and milling operators. But the sum of openings (defined as separations, retraining, and accessions) exceeds the number of displaced jobs. No lay offs due to the introduction of robots occurs.

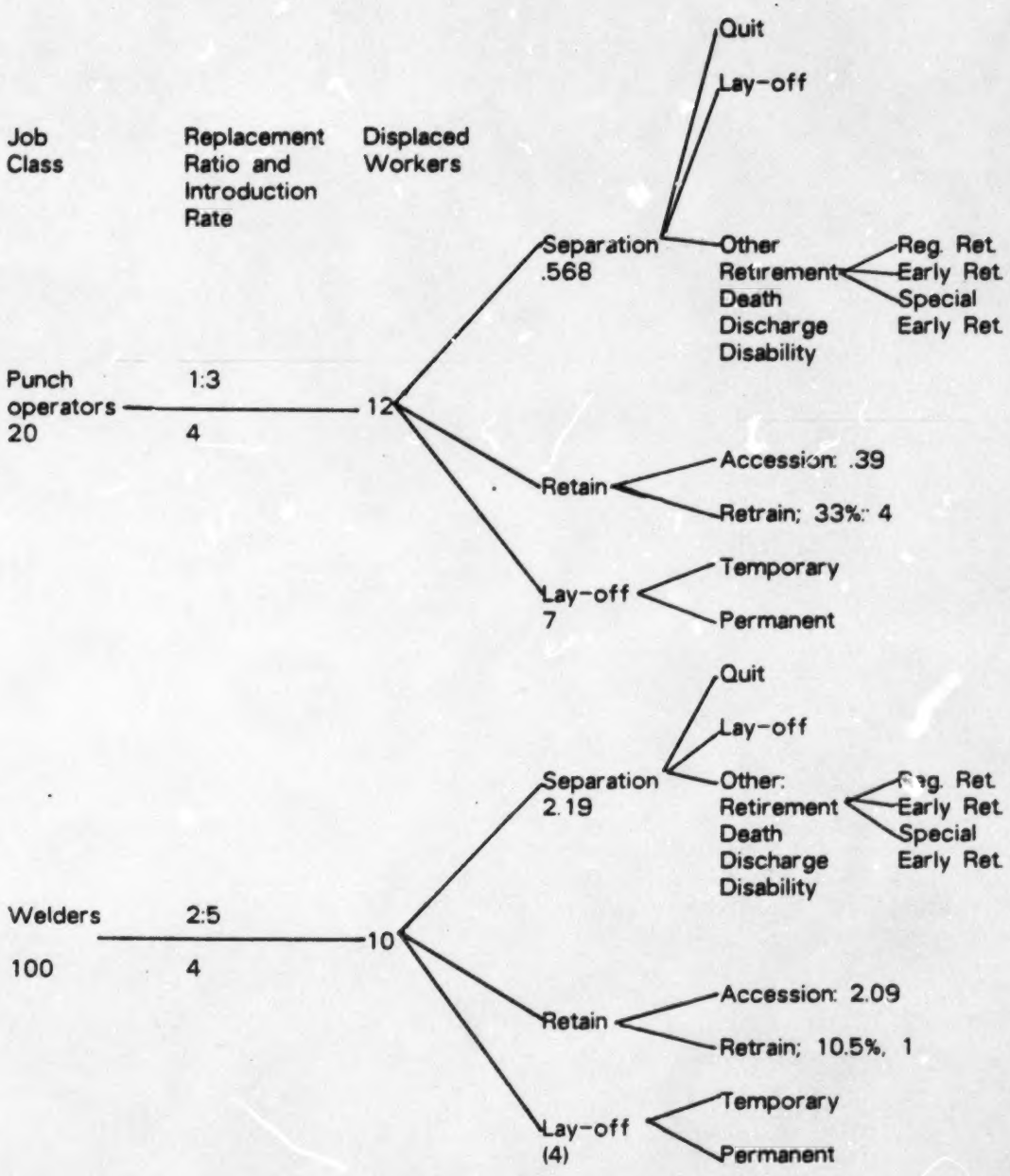
The example of the punch press operators depicts a different scenario. Here, 450 workers face potential displacement. This value of 450 is less than the sum of openings by a total of 91 persons. These 91 workers face lay offs and cannot be reabsorbed into this job class. Similarly for welders, the potential displacement number exceeded the sum of openings. Fifty-seven workers cannot be reabsorbed into this job class and they face being laid off.

Plant-wide Simulation

This type of simulation could be applied to a particular plant as well. The job class size is that of a plant or factory. It is assumed here that the separation and accession rates calculated for the job class in the state-wide industry will be the same in the specific location of the plant under scrutiny.

Plant management would likely have data on separation and accession rates for each employment class in their establishment. To estimate the number of openings at the plant level in the following example, it is assumed that the number of openings in a plant is proportional to the number of openings in the state for a particular job class in an industry.




Job Class
Replacement Ratio and Introduction Rate
Displaced Workers
Punch operators 20
1:3
4
12
Separation .568
Quit
Lay-off
Other
Retirement
Death
Discharge
Disability
Reg. Ret.
Early Ret.
Special Early Ret.
Retain
Accession: .39
Retrain; 33%: 4
Lay-off 7
Temporary
Permanent
Welders 100
2:5
4
10
Separation 2.19
Quit
Lay-off
Other:
Retirement
Death
Discharge
Disability
Reg. Ret.
Early Ret.
Special Early Ret.
Retain
Accession: 2.09
Retrain; 10.5%, 1
Lay-off (4)
Temporary
Permanent

IV.5 PLANT-WIDE SIMULATION RESULTS

Plant-wide job class size divided by the state-wide job class size yields a value called the plant factor, or pf. Multiplying the state-wide magnitudes for separation (and its divisions; quit, lay off and other) and accession by the plant factor yields magnitudes for these categories on a plant-wide basis. These values are the number of openings in the entire state which occur in the particular plant.

The value for retraining ratio stays the same, and the magnitude of this class remains the product of the retraining ratio and the number of displaced workers, as before.

In the case of lathe operators, a factory/plant population of 50 is selected arbitrarily. The plant factor is 50 divided by 7,390, or .00676. If five robots are introduced, 10 workers are displaced.

separation value of 216 x pf = 1.46

accession value of 167 x pf = 1.12

retraining factor of .375 x 10 = 3.75

10 - (1.46 + 1.12 + 3.75) = 3.67 laid off (minimum of 3)

In the case of punch press operators, a plant population of 20 is selected. The plant factor equals 20 divided by 4,362, or .00458. If four robots are introduced, 12 workers are displaced.

separation value of 124 x pf = .568

accession value of 85 x pf = .39

retraining factor of .33 x 12 = 4

12 - (.568 + .39 + 4) = 7 laid off

A plant population if 100 is selected for the welder class. The plant factor, 100 divided by 11,705, equals .00854. Four robots are introduced, and 10 workers are displaced.

separation value of 257 x pf = 2.19

accession value of 245 x pf = 2.09

retraining factor of .105 x 10 = 1.05

10 - (2.19 + 2.09 + 1.05) = 4.67 laid off (minimum of 4)

V. APPENDIX E EFFECTS OF AGE DISTRIBUTION ON UNIONS

Dr. Henry Farber of M.I.T. formulated a model based on the relationship between the age distribution of the United Mine Workers Union and their demand for future benefits (FB) versus present benefits (PB). Future benefits include those benefits negotiated by the union which do not accrue to their members until a future time. These include pensions, medical benefits, and death benefits. Present benefits on the other hand include such things as wages, paid personal holidays, and hours of work.

Farber constructs a curve like that shown in Figure 8-1 in which the ratio, FB/PB, is plotted for various ages. One can assume that this ratio approximately equals zero for young workers, since they could benefit more from wages than from retirement benefits, and approaches infinity for older members because of their nearness to retirement. Since unions vote in a democratic fashion, FB and/or PB proposals that adversely affect the largest number of members will gain the least support. Therefore, with regards to FB and PB, union demands should be representative of the median-aged worker.

Farbers' model is heavily dependent on theory. The applicability of this model to real world challenges facing unions is questionable. However, the model does provide some valuable insight to the importance of age distribution in the formulation of union policy.

The lower portion of Figure 8-1 represents the approximate cumulative age distribution of the UMW. In this graph, the height of the curve indicates the proportion of members who are less than a particular age. Thus, 50% are younger than 45, the median age of the union's members.

In Figure 8-1 can see which ratio FB/PB, the median-aged worker prefers. Not only would these two graphs help unions in formulating contract demands, the bottom graph would help in evaluating the feasibility of various technological innovations proposed by management with respect to the age distribution of workers.

The age distribution of the union membership will affect the feasibility of the lay off alternatives. It is also important in determining how many people will be able to retire at age 65 in say, five years, assuming that those age 60 will remain in their present occupation for another five years.

Age distribution is also important in determining the costs and feasibility of special retirement plans, those plans which become necessary as an alternative during plant closings and permanent lay offs. If the management of a firm in Illinois faces the same distribution in its plant, and as a feasible alternative is considering a special retirement plan of $40,000

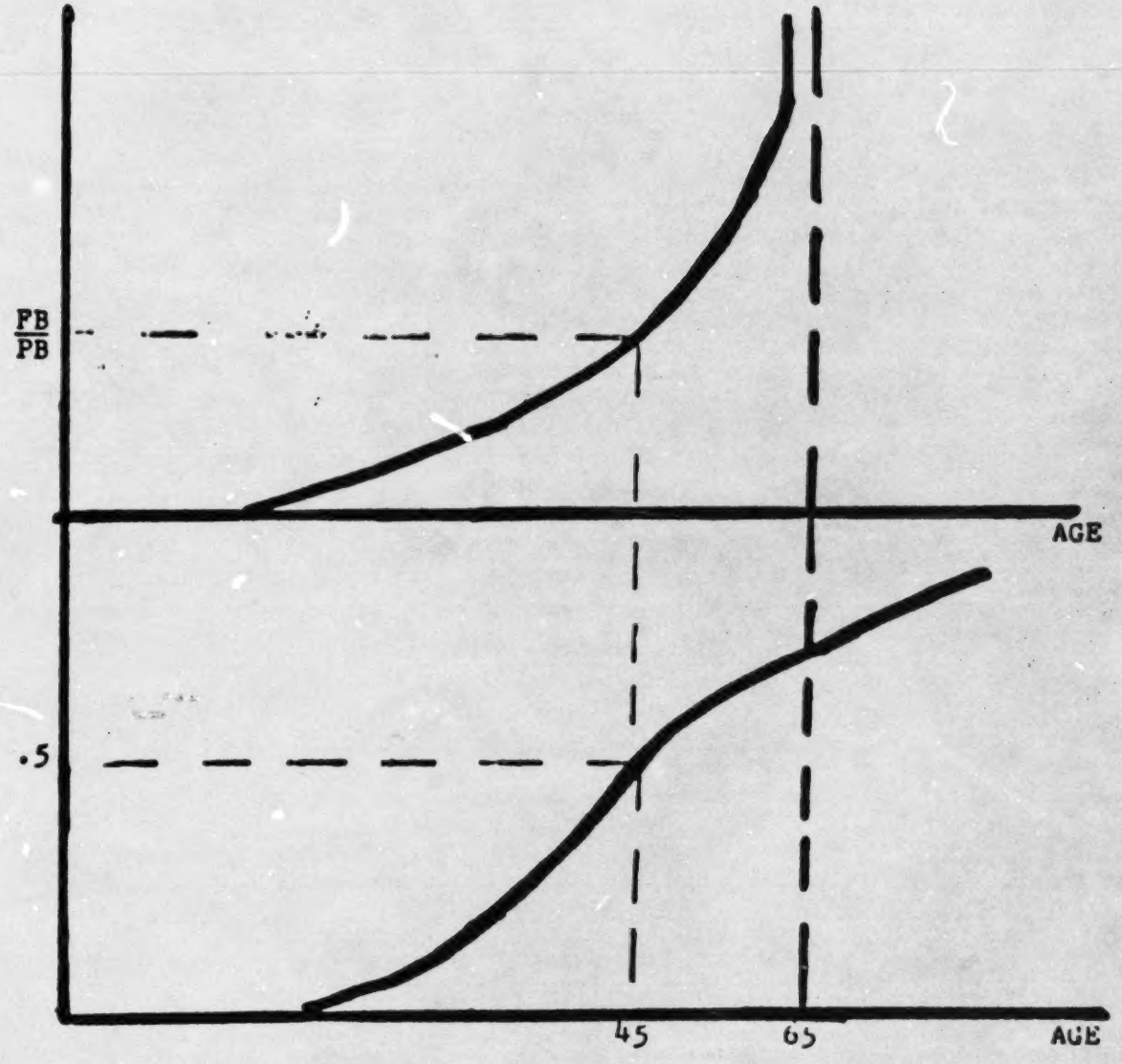
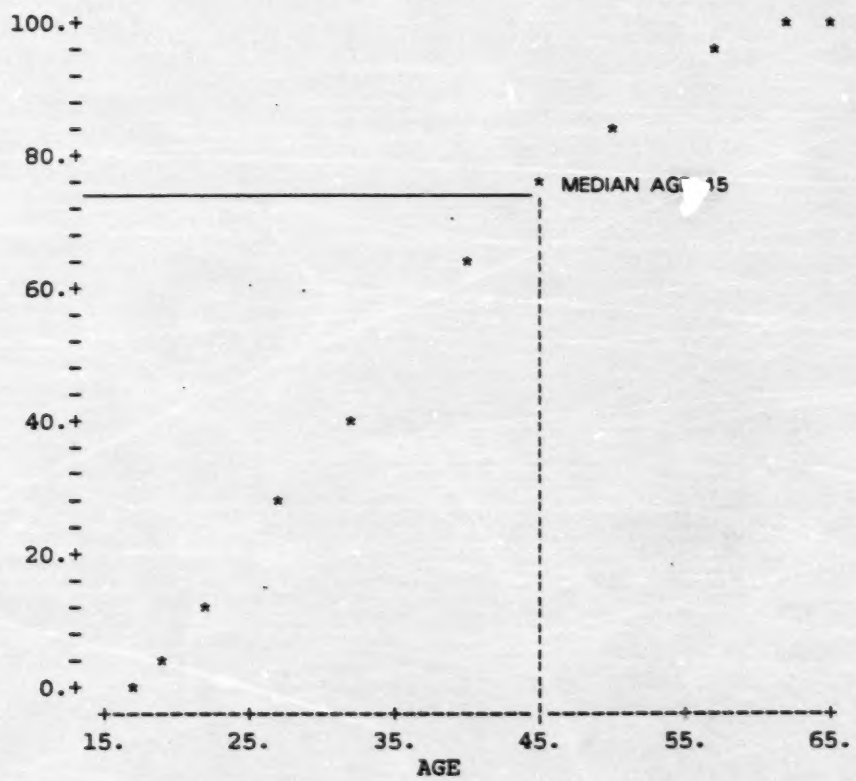


Figure 8-1: OPTIMAL FB/PB AS A FUNCION OF AGE

per worker for 40% of its employees, they must retire those who are approximately 35 years old or older. Furthermore, if they employ 100 welders and flamecutters, this means that 40 workers will be able to retire under this plan at a cost to the plant of $1,600,000 (40 X $40,000).

Figure 8-2 shows a typical cumulative age distribution for production workers. The median-age is marked, and lies around 35-39 for each job class. According to date from 1970 Census of Population, the average age distributions of production workers on the national level are much the same as the distributions broken by individual occupations, or by industry. At the time of this writing, 1980 Census data was not yet available.

Figure 8-2: TYPICAL CUMULATIVE AGE DISTRIBUTION FOR PRODUCTION WORKERS



VI. APPENDIX F SUPPLEMENTARY HUMAN RESOURCE MATERIAL

The following tables consist of additional information pertaining to the Maintenance and Operation issue found in Chapter 6. They include details obtained through interviews and comprise important information that, although not used in the chapter, are no less important. The companies interviewed were PRAB Conveyors, Inc.; Unimation, and Cincinnati Milacron. Answers obtained from each interview as well as questions asked are provided.

ROBOT MANUFACTURER'S MAINTENANCE AND OPERATION TRAINING PROGRAMS

	PRAB	UNIMATION	CINCINNATI
Do you meet your customer's demand for employee training in the Maintenance/Operation of Robots?	1	1	1
Are you currently operating your training programs at their maximum capacity?	1	1	1
Currently, are displaced workers being retrained in the area of robot maintenance and operation?	1	1	1
Are these displaced workers retrainable in the area of robot maintenance and operation?	1	1	1
Do you promote robot maintenance and operation autonomy for your clientele in your training programs?	1	1	1
Is the rate of robot introduction into the marketplace being hindered by the lack of trained maintenance and support people available?	0	0	0
Currently, is the demand for your training services greater than what your firm can supply?	0	0	0

Key: 1=yes, 0=no.

	PRAB		UNIMATION		CINCINNATI	
	PRAB ROBOT	VERSA-TRAN ROBOT	2000 ROBOT	4000 ROBOT	SIMPLE ROBOT	COMPLEX ROBOT
How many people can you train per-annum approximately?	400	288	450	420	-	-
What is the size of training classes?	10-12	10	10-12	10-12	-	-
Length of your training programs?	1.5-2 days	4 days	1.5-2 days	4 days	2wks	2wks
Cost of training programs?	$150/p	$500/p	-	-	$750/wk	$175/day
Skills required to be trained in robot maintenance and operation.						
1. mechanical	x	x	x	x	-	-
2. hydraulic valves	x	x	x	x	-	x
3. electrical	x	x	x	x	-	x
4. electronics	-	x	-	x	-	x
5. programming	-	-	-	-	-	x
6. numerical controls	-	-	x	x	-	-
7. preventive main.	x	-	-	-	x	-
Skills required after training to operate and maintain robots.						
1. mechanical	x	x	x	x	-	x
2. hydraulic valves	x	x	x	x	-	x
3. electrical	x	x	x	x	-	x
4. electronics	-	x	-	x	-	x
5. programming	x	x	x	x	-	x
6. numerical controls	x	-	x	x	x	-
7. preventive main.	x	-	x	x	x	-
Approximate range of individual unit sales	1-50	1-50	1-50	1-50	1-100	1-100

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